Mars Global Surveyor

Deep Space Network Initial Acquisition Geometry Report

July 1996

Jet Propulsion Laboratory
California Institute of Technology

JPL D-13721

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Deep Space Network
Initial Acquisition Geometry Report

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Acknowledgments

Steve Williams provided valuable insights into the MASL Plot Library, and Jess Fordyce and Ralph Roncoli's Mars Observer DSN Geometry examples served to verify new algorithms. Dan Johnston provided several suggestions and reviewed the final draft.

Questions or comments can be submitted to Daren Casey at the address below.

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1.0 INTRODUCTION

1.1 PURPOSE

The Deep Space Network (DSN) Initial Acquisition Geometry Report provides data describing the geometry of the Mars Global Surveyor (MGS) spacecraft relative to the tracking stations that will support initial acquisition of the spacecraft during the first few hours after launch. This report supports the development of the MGS Deep Space Network Initial Acquisition Plan.

The initial acquisition geometry data were generated using a preliminary release of the McDonnell Douglas Aerospace (MDA) Detailed Test Objectives (DTO) report[1]. No significant changes are anticipated in the final release.

The majority of the data included in this report is presented in the form of plots indicating the time histories of quantities such as spacecraft range and range rate, azimuth and elevation angles and rates, as viewed by several tracking stations. All of the plots begin at Delta third engine cutoff (TECO) or burnout and end 6 hours later. Also included in this report are spacecraft groundtrack plots on a Mercator map projection annotated with key launch vehicle and spacecraft events from TECO to approximately one day later. A timeline of the key launch vehicle and spacecraft events for each launch opportunity is also included. In addition, this report contains data regarding the pointing of the spacecraft low gain antenna (LGA) relative to the tracking stations.

1.2 SCOPE

This report contains data associated with the initial acquisition of the MGS spacecraft for each of the 30 nominal launch opportunities in the MGS launch period. Data for dispersed or off-nominal trajectories are not presented. Early launches by 30 seconds in response to collision avoidance warnings were not considered.

[1] "Detailed Test Objectives Trajectories for the Mars Global Surveyor Spacecraft Mission - CDRL C3-04 - Contract NAS5-30722", McDonnell Douglas Memorandum A3-L230-M-96-XXX, May 1996

2.0 LAUNCH EVENTS

2.1 LAUNCH PERIOD / LAUNCH WINDOW

The MGS flight to Mars begins aboard the McDonnell Douglas Delta II 7925A launch vehicle at Space Launch Complex 17 (SLC-17) Pad A, Cape Canaveral Air Station in Florida. The 20-day launch period begins on November 6, 1996 and continues to November 25, 1996.

Traditional launch "windows" of minutes or hours are not possible with the Delta II launch vehicle for an interplanetary flight. The launch azimuth, the angle from true North to the initial groundtrack, determines the ascent trajectory plane. This plane must contain the launch site, center of the Earth, and final outgoing flight path known as the departure asymptote. As the Earth rotates the launch site moves relative to the departure asymptote and the required azimuth changes. Since the Delta II does not have a variable azimuth capability launch must occur within a very small window (about 1 second) at a fixed launch azimuth.

The required interplanetary injection targets vary during this period due the changing Earth-Mars orientation. Energy, declination, and right ascension targets for each day in the period have been provided to McDonnell Douglas[2]. Liftoff times determined for each launch opportunity are then rounded to the nearest integer second to fulfill Eastern Test Range (ETR) requirements. For example, the calculated liftoff time on November 6th of 17:11:16.703 UTC will become 17:11:17 UTC. Note that the calculated liftoff times (non-integer) are used throughout this report.

In addition to the nominal (integer) liftoff time, an opportunity to launch 30 seconds early will be used <u>only</u> in the event of an ETR Collision Avoidance warning (COLA). These warnings would be issued if there were potential conflicts between the Delta flight path and orbits of other spacecraft. In this event the launch would occur 30 seconds before the nominal liftoff time, though the Delta flight path relative to the Earth would not change. This preserves the viewing geometry from ground tracking stations but shifts absolute event times by 30 seconds.

In order to enhance launch probabilities during the November 1996 Mars opportunity, the MGS Project is employing a launch strategy using dual launch azimuths for the first part of the MGS launch period. This strategy is based on the selection of two azimuths that satisfy liftoff time separation (ΔT) constraints imposed by Delta II launch operations. These constraints require the liftoff times associated with the two launch azimuths (Σ) be between 64 and 78 minutes apart:

$$64 \text{ min} \leq (\text{Liftoff Time } \Sigma_{L2}) - (\text{Liftoff Time } \Sigma_{L1}) \leq 78 \text{ min}$$

where the limiting values are:

64 min - time required to reload Delta guidance parameters (for new azimuth)

78 min - time to commence liquid oxygen (LOX) unloading.

[2] "Mars Global Surveyor Delta II 7925A Target Specification", JPL D-12728 (MGS 542-411), Final, February 1996

Table 1 shows the launch azimuths required during the launch period. The azimuth pair 93° and 99.89° provides liftoff time separations of just over 64 minutes on November 6, 1996 and just under 78 minutes on November 15, 1996. The declination targets in the second part of the launch period require increasingly higher launch azimuths, up to the maximum allowed of 110°, resulting in the choice of 110° for all launches in this period.

Table 1 - MGS Launch Azimuths

Launch Date	Launch Azimuth Σ_L
06-Nov - 15-Nov	93° and 99.89°
16-Nov - 25-Nov	110°

2.2 DELTA II LAUNCH / INJECTION PROFILE

Figure 1 shows the overall Delta II launch profile. Following liftoff (event #1), first stage flight continues until main engine cutoff (MECO) (event #2) at 260.7 seconds Mission Elapsed Time (MET) followed by stage one separation. The boost profile continues with powered flight by the second stage until the 185 km (100 nautical mile) parking orbit is achieved at the first cutoff of the second stage (SECO-1) (event #3). Only three boost to orbit trajectories are required for the entire launch period, one for each launch azimuth.

After a coast period that places the final outgoing flight path at the proper angle from the plane of the equator, the second stage is restarted for approximately two minutes, raising the apoapsis of the parking orbit (event #4). Fifty (50) seconds after SECO-2 the Delta third stage / MGS spacecraft combination is spun up to 60 rpm for the spin-stabilized third stage burn. Ninety (90) seconds after SECO-2, third stage ignition occurs and the spacecraft is injected onto its interplanetary transfer trajectory at third stage engine cutoff (TECO) (event #5). Separation of the Delta third stage from the MGS spacecraft occurs less than five minutes after burnout (TECO).

Since the Delta flies a fixed ascent trajectory to the parking orbit and the third stage is a solid rocket motor providing a fixed velocity change, the second stage restart and burn times and burn attitude are varied to provide the required Earth-departure conditions. This results in a different trajectory from SECO-1 to the targeting interface point (TIP) for each launch opportunity. A timeline of launch events is shown in Figure 2.

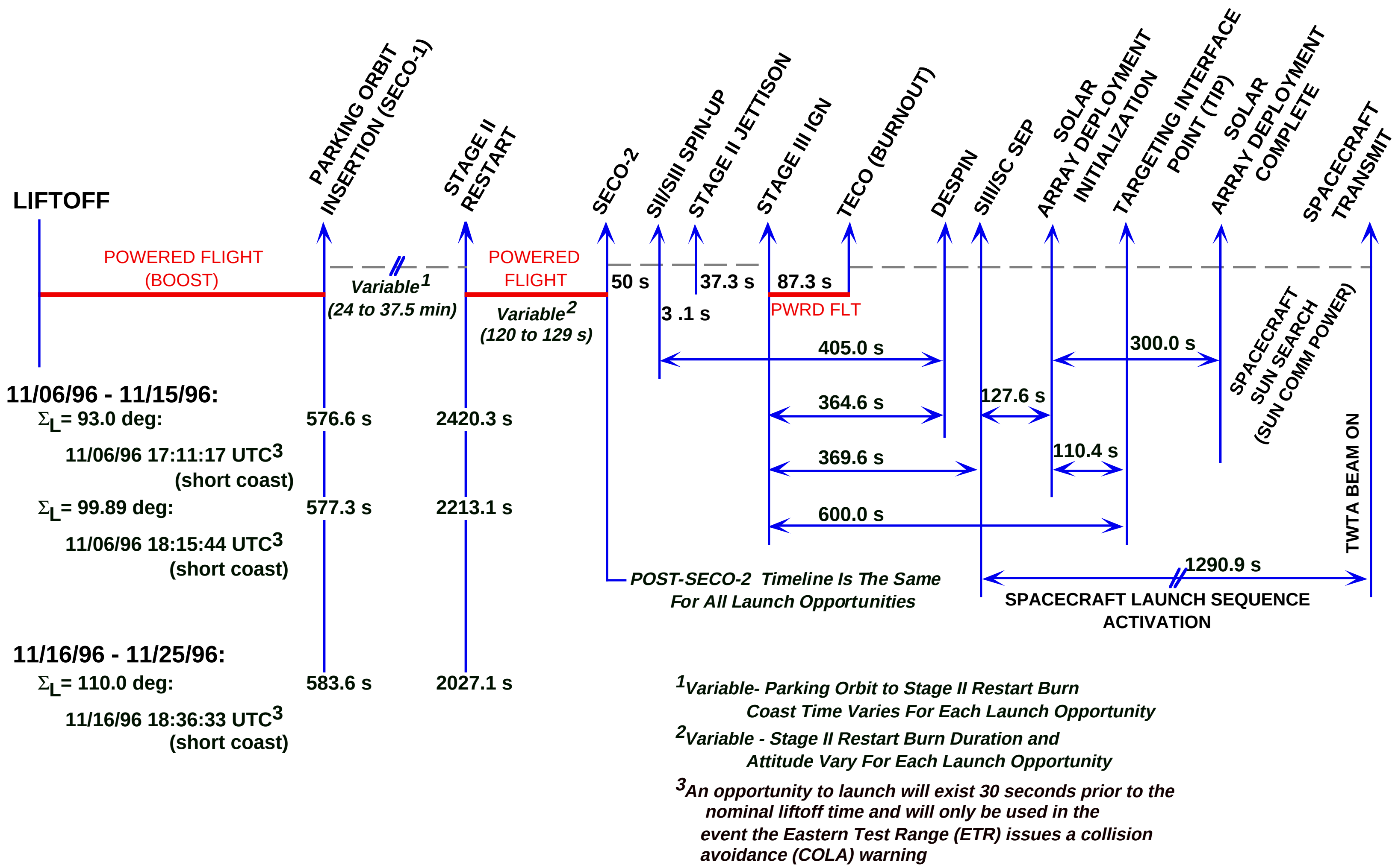

Figure 1 - MGS / Delta II Launch Overview

1. **Liftoff (time varies each launch day)**

2. **MECO**
   1st Stage main engine cut-off
   2nd Stage ignition
   (same time for given launch azimuth)

3. **SECO-1**
   2nd Stage cut-off #1
   (same time for given launch azimuth)

4. **2nd Stage Restart / SECO-2**
   ~Two minute burn raises apogee
   (Burn start time, duration, and
   attitude varies each launch day
   => depends on required C3)

5. **3rd Stage Ignition / TECO**
   87.3 s burn puts MGS spacecraft on
   hyperbolic escape trajectory (burn
   duration same for all launch days with
   burn start always 90.4 s after SECO-2)

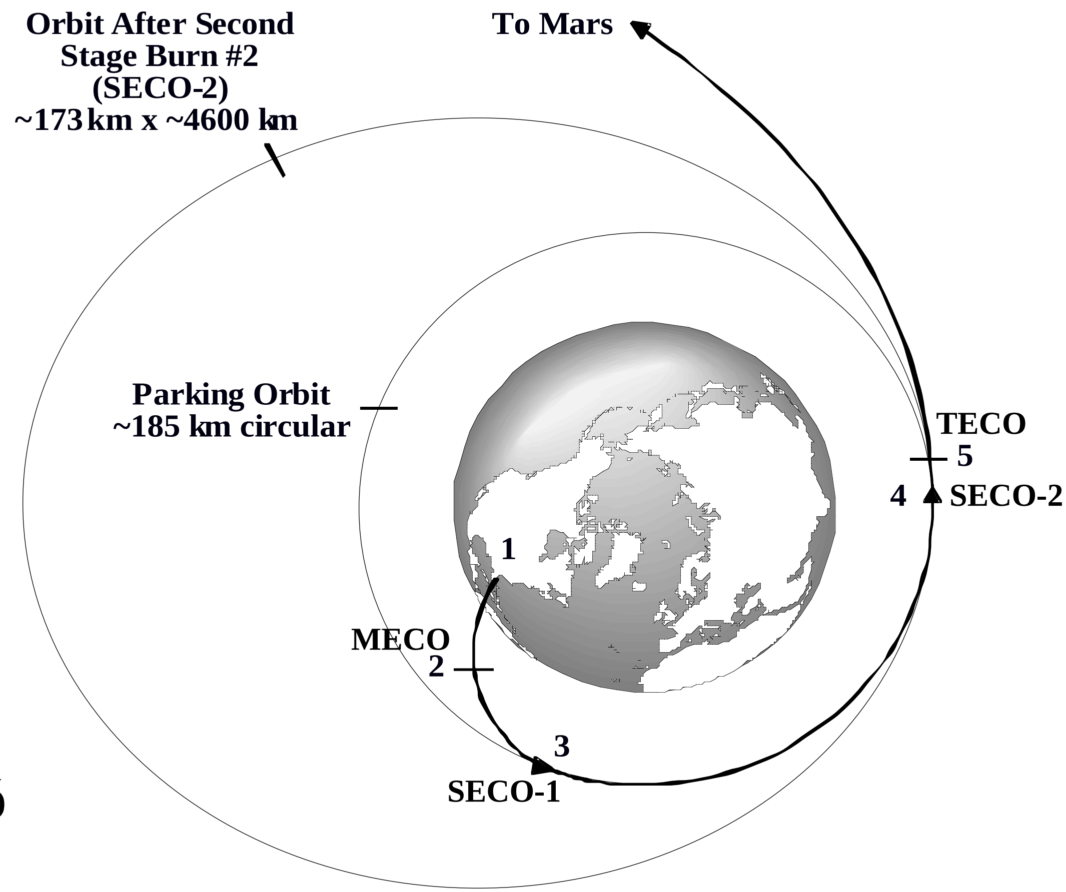

Figure 2 - MGS / Delta II Launch Event Timeline

2.3 SPACECRAFT POST-SEPARATION EVENTS[3]

MGS activates its post-separation command sequence once separation from the third stage is detected. The timeline of spacecraft events is shown in Figure 3.

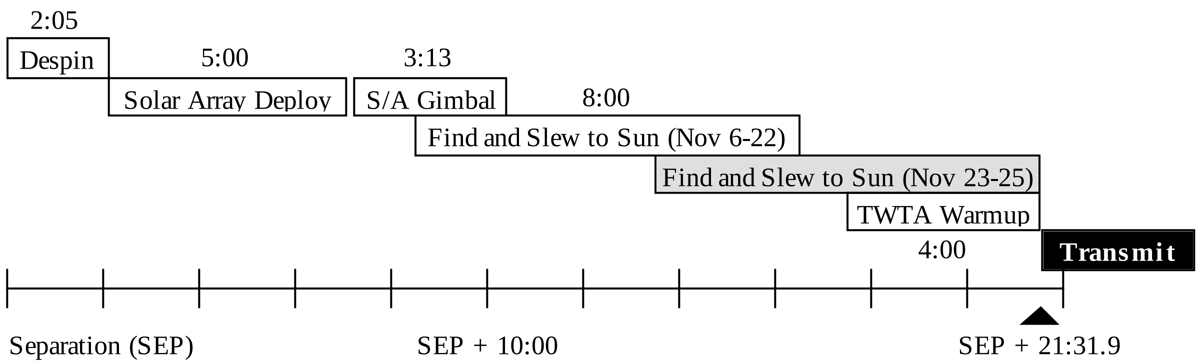

Figure 3 - Spacecraft Post-Separation Timeline

In the first two minutes the launch despin control mode removes any residual spin and holds attitude, followed by five minutes for solar array (S/A) deployment. The solar arrays then rotate to their cruise orientation, the "Array Normal Spin" configuration, shown in Figure 4.

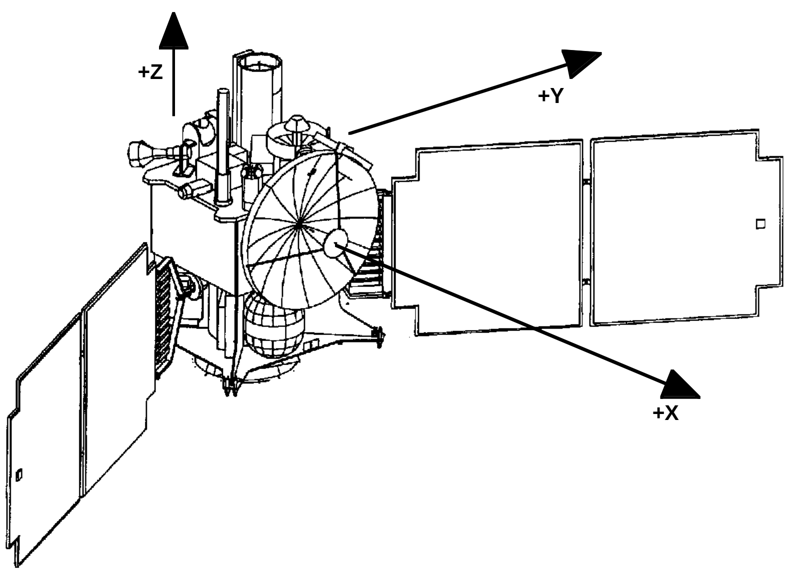

Figure 4 - MGS Array Normal Spin Configuration

After eclipse exit, eight minutes is used to find and slew the +X axis to the Sun. The Traveling Wave Tube Amplifier (TWTA) filament is powered on and warms up for 4 minutes. Downlink at 2000 bits per second (bps) through the Low Gain Antenna (LGA) occurs approximately 21.5 minutes after separation.

[3] "Mars Global Surveyor Spacecraft Launch Event Timeline", JPL D-12888 (MGS 542-SE-014), Draft Revision B, February 1996

2.4 SPACECRAFT ATTITUDE

In the post-solar array deployment attitude, "Sun Comm Power", the LGA aligned with the +X axis will be pointed at the Sun as the spacecraft spins about the +X axis at 0.01 rpm. This allows adequate communication performance and good illumination of the solar arrays.

This orientation will be maintained for two hours, when the attitude initialization sequence begins. In order to establish a 3-axis attitude reference, the spacecraft scans the celestial star sensor across the sky to identify known stars. To accomplish this, the +X axis is oriented 60° off-Sun and the spacecraft "rolls" about the MGS-Sun axis so that the +X axis "cones" around the Sun once every 100 minutes. During this phase the off-point or aspect angle of the LGA antenna with respect to the Earth will vary by ±60°, resulting in periods of poor or no reception of MGS downlink at DSN stations. The attitude initialization sequence is expected to take no more than 2 revolutions, or 200 minutes. After initialization is complete MGS will reorient to the "inner cruise" attitude with the +X axis in the plane of the Earth and Sun, 60° off-Sun[4], spinning about the +X axis at 0.01 rpm.

In the event of an anomaly causing the spacecraft to enter safe mode, the first transmission would occur 5 minutes earlier than nominal at 10 bps with the spacecraft in the Sun-coning attitude initialization mode.

2.5 LAUNCH EVENT SUMMARY

Table 2 shows the times of key events.

[4] E. J. Graat, "Mars Global Surveyor Launch & Cruise Lockfile Version 1.0," JPL Interoffice Memorandum MGS-MOS-96-045, 29 April 1996

Table 2 - Liftoff Times and Key Events (UTC and seconds MET)

Launch Date	Azimuth	Liftoff UTC	SECO-1	SECO-2	TECO	Separation	TIP	First Transmit
06-Nov-96	93°	17:11:16.703	576.59	2547.75	2725.44	3007.71	3238.13	4299.61
	99.89°	18:15:44.259	577.32	2340.53	2518.22	2800.49	3030.91	4092.39
07-Nov-96	93°	17:00:49.868	576.59	2567.64	2745.33	3027.60	3258.02	4319.50
	99.89°	18:05:56.373	577.32	2358.36	2536.05	2818.32	3048.74	4110.22
08-Nov-96	93°	16:48:11.067	576.59	2592.83	2770.52	3052.79	3283.21	4344.69
	99.89°	17:54:09.165	577.32	2380.79	2558.48	2840.75	3071.17	4132.65
09-Nov-96	93°	16:35:20.282	576.59	2620.53	2798.22	3080.49	3310.91	4372.39
	99.89°	17:42:18.843	577.32	2405.26	2582.95	2865.22	3095.64	4157.12
10-Nov-96	93°	16:20:05.070	576.59	2653.98	2831.67	3113.94	3344.36	4405.84
	99.89°	17:28:22.767	577.32	2434.47	2612.16	2894.43	3124.85	4186.33
11-Nov-96	93°	16:04:46.636	576.59	2689.18	2866.87	3149.14	3379.56	4441.04
	99.89°	17:14:36.737	577.32	2464.82	2642.51	2924.78	3155.20	4216.68
12-Nov-96	93°	15:46:14.298	576.59	2733.12	2910.81	3193.08	3423.50	4484.98
	99.89°	16:58:14.522	577.32	2501.69	2679.38	2961.65	3192.07	4253.55
13-Nov-96	93°	15:24:50.394	576.59	2785.93	2963.62	3245.89	3476.31	4537.79
	99.89°	16:39:57.063	577.32	2544.53	2722.22	3004.49	3234.91	4296.39
14-Nov-96	93°	15:02:15.572	576.59	2844.14	3021.83	3304.10	3534.52	4596.00
	99.89°	16:15:21.110	577.32	2604.84	2782.53	3064.80	3295.22	4356.70
15-Nov-96	93°	14:29:58.334	576.59	2932.01	3109.70	3391.97	3622.39	4683.87
	99.89°	15:47:26.984	577.32	2677.44	2855.13	3137.40	3367.82	4429.30
16-Nov-96	110°	18:36:32.739	583.57	2147.36	2325.05	2607.32	2837.74	3899.22
17-Nov-96		18:21:17.203	583.57	2181.82	2359.51	2641.78	2872.20	3933.68
18-Nov-96		18:07:03.814	583.57	2214.36	2392.05	2674.32	2904.74	3966.22
19-Nov-96		17:52:40.260	583.57	2247.63	2425.32	2707.59	2938.01	3999.49
20-Nov-96		17:34:26.737	583.57	2291.76	2469.45	2751.72	2982.14	4043.62
21-Nov-96		17:17:37.190	583.57	2332.35	2510.04	2792.31	3022.73	4084.21
22-Nov-96		16:59:17.494	583.57	2377.40	2555.09	2837.36	3067.78	4129.26
23-Nov-96		16:33:03.787	583.57	2445.34	2623.03	2905.30	3135.72	4197.20
24-Nov-96		16:05:43.703	583.57	2516.65	2694.34	2976.61	3207.03	4268.51
25-Nov-96		15:09:45.010	583.57	2671.74	2849.43	3131.70	3362.12	4423.60

3.0 DSN INITIAL ACQUISITION GEOMETRY

3.1 INITIAL ACQUISITION

The initial acquisition of the MGS spacecraft by the Deep Space Network is a critical event in the early mission phase. The tracking data obtained in the first two hours is used to predict the spacecraft position for subsequent tracking passes, and must be accurate enough to point the narrow-beam 34 meter High Efficiency (HEF) antennas.

The first DSN complex able to acquire the X-band downlink from MGS is Canberra. The primary method of initial acquisition of the spacecraft signal is through the use of the X-band Acquisition Aid (ACQ-AID), a 4 foot diameter antenna mounted on the 26 meter antenna. The 26 m antennas are uniquely suited to the initial acquisition role with their high slew rates and ability to automatically track a spacecraft signal. As the 2.4° beamwidth[5] ACQ-AID tracks the spacecraft, its pointing information is used to orient the 0.063° beamwidth[6] 34 m HEF antenna. Without direction from the acquisition aid system, it would be very difficult for the narrow beamwidth HEF antenna to find the spacecraft.

Two-way spacecraft tracking is the normal mode and provides the most accurate Doppler measurements[7]. The spacecraft tracks the phase of the uplink signal and generates a downlink which is coherent with it. Under normal circumstances it may require up to 30 minutes for the HEF antenna to establish a coherent two-way lock on the downlink signal. Approximately 100 minutes after first transmission, the range to the spacecraft exceeds the usable range of the ACQ-AID, estimated to be 40,000 km (at a 2000 bps data rate).

A secondary method of acquiring the spacecraft is via the S-band signal transmitted by the Delta third stage until its batteries are depleted. The 8.7° beamwidth S-band ACQ-AID on the 26 m antenna would track the third stage and direct the 34 m HEF pointing.

3.2 TRACKING STATION LOCATIONS

Deep Space Network station locations used in this report were obtained from the DSN/Flight Project Interface Design Handbook and are given in Table 3.

Table 3 - DSN Station Locations[8]

Station	Geocentric Radius (km)	Geocentric Latitude (deg)	East Longitude (deg)
Goldstone			
DSS 15 - 34 m HEF	6371.966	35.240	243.113
DSS 16 - 26 m (ACQ-AID)	6371.964	35.160	243.126
Canberra			
DSS 45 - 34 m HEF	6371.676	-35.217	148.978
DSS 46 - 26 m (ACQ-AID)	6371.676	-35.224	148.983
Madrid			
DSS 65 - 34 m HEF	6370.022	40.237	355.749

[5] Stephen F. Brown, personal communication, 17 June 1996

[6] "Deep Space Network / Flight Project Interface Design Handbook", JPL 810-5, Rev. D, Vol. 1, Module TCI-30, Rev. D, 1 May 1992, p. 17

[7] JPL 810-5, Rev. D, Vol. 1, Module TRK-40, 15 March 1990, p. 5

[8] JPL 810-5, Rev. D, Vol. 1, Module GEO-10, Rev. D, 1 April 1989, p. 21

3.3 ANTENNA POINTING

The 34 m HEF antennas are pointed using an azimuth-elevation mount. A point in the sky is given by the azimuth angle measured from true North and the elevation angle from the horizon. The 26 m antennas employ an "X-Y" mount, where the X-axis allows steering in the North-South plane and the Y-axis out of this plane. "Keyholes" at the East and West horizons are mechanical limits where the 26 m antennas cannot be pointed. These are a factor for MGS at Goldstone on certain launch days, delaying the rise time.

3.4 ACQUISITION GEOMETRY HIGHLIGHTS

The following table shows general geometric conditions and items that impact initial acquisition for that launch opportunity. Terms used are defined in the next section.

Table 4 - Acquisition Geometry Highlights

Launch Opportunity	Canberra Notes		Goldstone Notes	
	Elevation	Aspect, Other	Elevation	Aspect, Other
06 Nov, 93°	30-40°, decreasing daily	15 minutes of transmit before aspect > 90°, improving daily	<10°, increasing daily	Rise in keyhole, improving daily
06 Nov, 99.89°	30-40°, decreasing daily	20 minutes of transmit before aspect > 90°	Below horizon	
10 Nov, 93°	25-30°	30 minutes of transmit before aspect > 90°	18° max	40 minutes of contact before aspect > 90°
10 Nov, 99.89°	30-35°	45 minutes of transmit before aspect > 90°	5° max, increasing daily	Rise in keyhole, improving daily
15 Nov, 93°	10°	<90°	35° max	<85°
15 Nov, 99.89°	20-25°	<90°	20° max	<85°
16 Nov	30° max	<90°	Below horizon	
20 Nov	20-28°	<80°	Below horizon	
25 Nov	10°	<75°	20 ° max	<70°

- The spacecraft is above the horizon at Canberra before transmission begins throughout the launch period.
- The opening of the period provides favorable elevations at Canberra, though the LGA aspect angle quickly exceeds 90°.
- At the end of both the two-a-day and 110° azimuth launch periods Canberra elevations are low, with Goldstone available as a backup.
- At the end of the launch period elevations at both Canberra and Goldstone are below the recommended limit for use of the ACQ-AID.
- Madrid is usable for the early 110° azimuth launch days, but MGS doesn't rise until 4.5 hours after the first transmit.

3.5 NEAR EARTH GEOMETRY

This section presents data necessary for DSN initial acquisition planning. Definitions followed by plots of the key parameters are given below.

3.5.1 RANGE

The range or distance between the station and spacecraft determines the strength of signals received at the station.

3.5.2 ELEVATION ANGLE

Elevation is the angle between the local horizon and line-of-sight to the spacecraft. Higher elevations normally mean better performance since there is less atmosphere for the signal to travel through.

Due to multipath effects, where portions of the spacecraft signal are reflected off local terrain or structures before arriving at the receiving antenna, use of the ACQ-AID antenna at elevation angles less than 20° is not recommended[9].

3.5.3 RANGE RATE

The rate of change of spacecraft range, along the line-of-sight to the station, is proportional to the Doppler frequency shift of the received signal. The expected frequency shift is used to plan the receiver settings for acquisition.

3.5.4 LGA ASPECT ANGLE

The angle between the Low Gain Antenna boresight and the station affects the strength of the received signal. The LGA performs best at a zero aspect angle, where the center of the main beam is directed at the station. The power decreases as the aspect angle increases.

The MGS LGA is expected to be usable to an aspect angle of 105°. This limit is not exceeded on any launch opportunity.

3.5.5 AZIMUTH AND ELEVATION RATE, X-Y RATE

Antennas are limited in the allowed rates in different axes. Maximum tracking rate for the 34 m HEF Az-El mount is 0.4°/s, and 3°/s for the 26 m X-Y mount[10]. Azimuth and elevation rates are shown for the 34 m HEF antennas and X- and Y-axis rates are shown for the 26 m antennas.

3.5.6 GEOMETRY PLOTS

The first series of plots shows range, elevation angle, range rate, aspect angle, azimuth rate, elevation rate, and X-Y angular rate for each launch opportunity as a function of time since third engine cutoff (TECO). The time scale is 0-6 hours. The next set shows range, elevation angle, range rate, and aspect angle from 6-24 hours for three launch opportunities (November 6th, both azimuths, and November 16th).

Data is shown only when the elevation is greater than zero, indicating when the spacecraft is in view. Local terrain, obstructions, and mechanical limits are not accounted for.

Plot symbols are C for Canberra, G for Goldstone, and M for Madrid. An asterisk (*) is plotted when the transmitter comes on. The flight path before the transmitter is activated is shown as a line with no plot symbols on the azimuth-elevation stereo plot.

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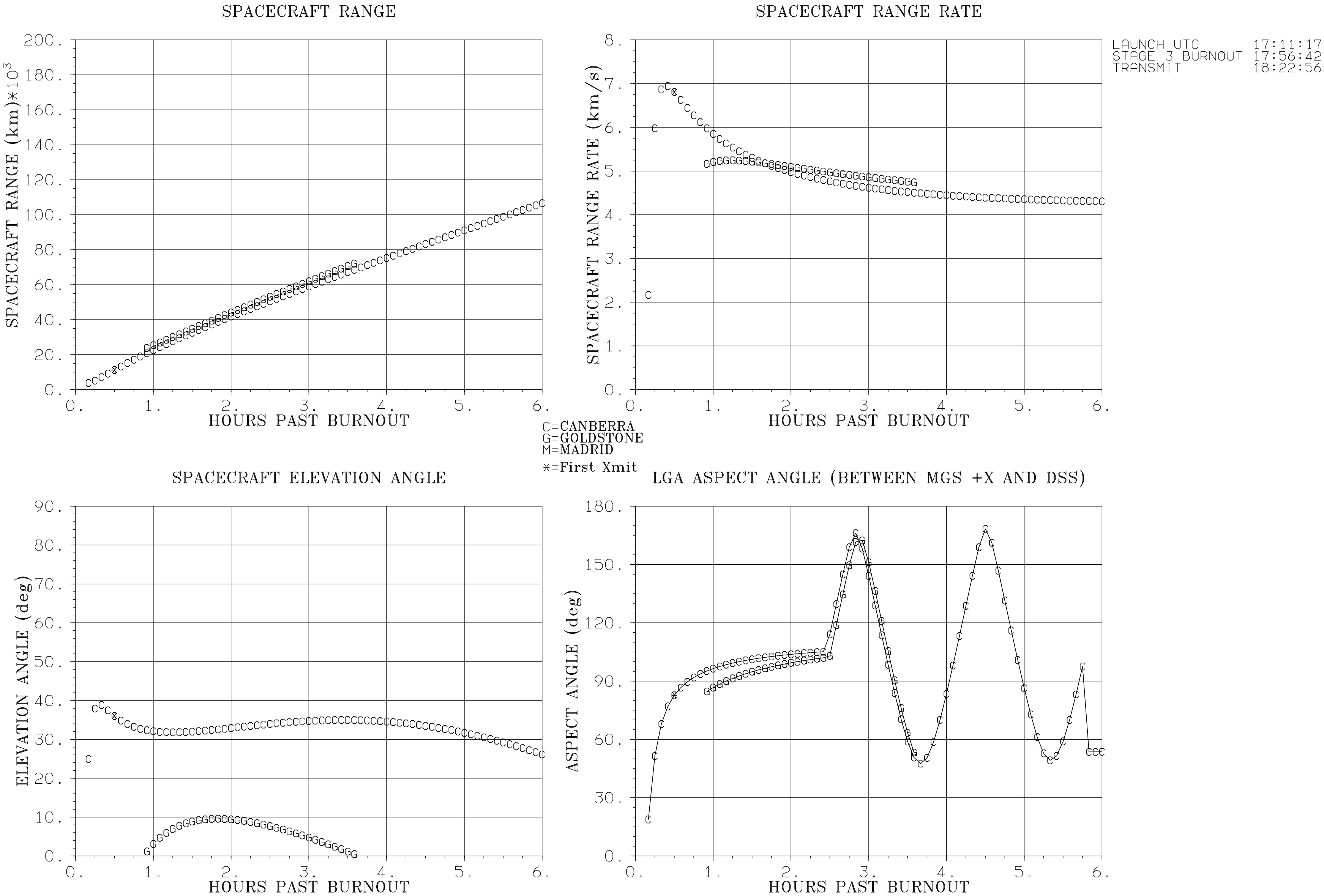
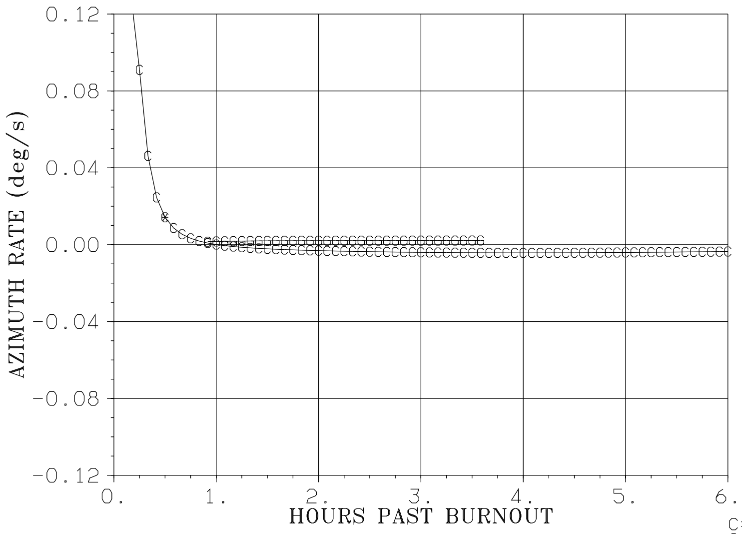
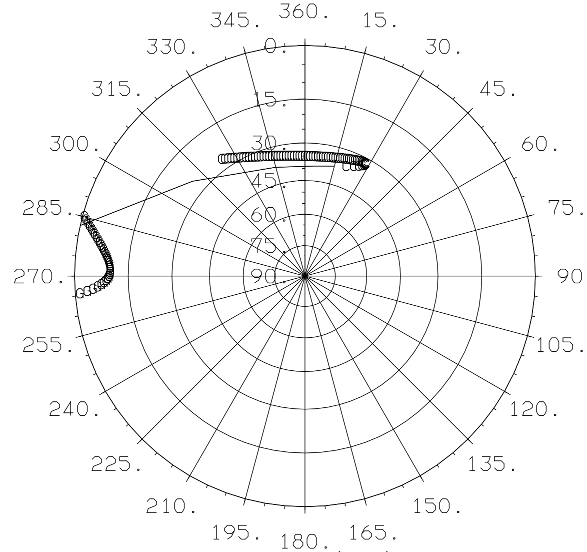
[9] JPL 810-5, Rev. D, Vol. 1, Module TRK-10, Rev. D, 15 March 1988, p. 8
[10] JPL 810-5, Rev. D, Vol. 1, Module TRK-10, Rev D., 15 March 1988, p. 5

MGS DSN Acq - Launch 06 Nov 96 - 93 Az



MGS DSN Acq – Launch 06 Nov 96 – 93 Az



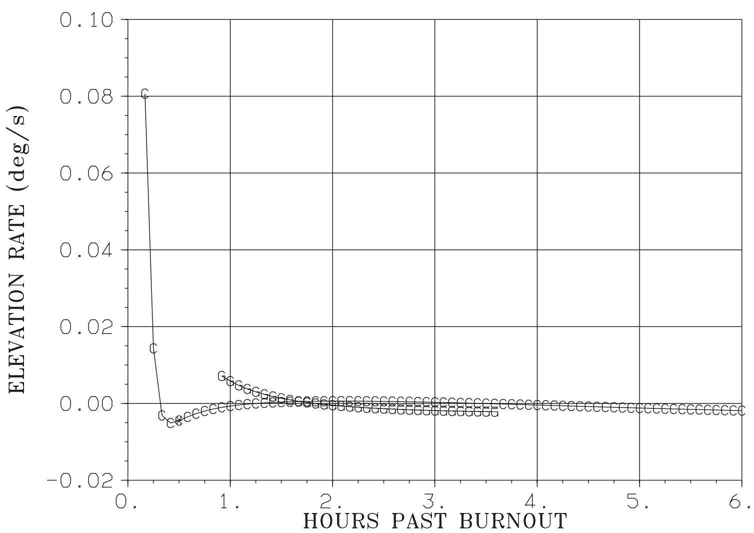


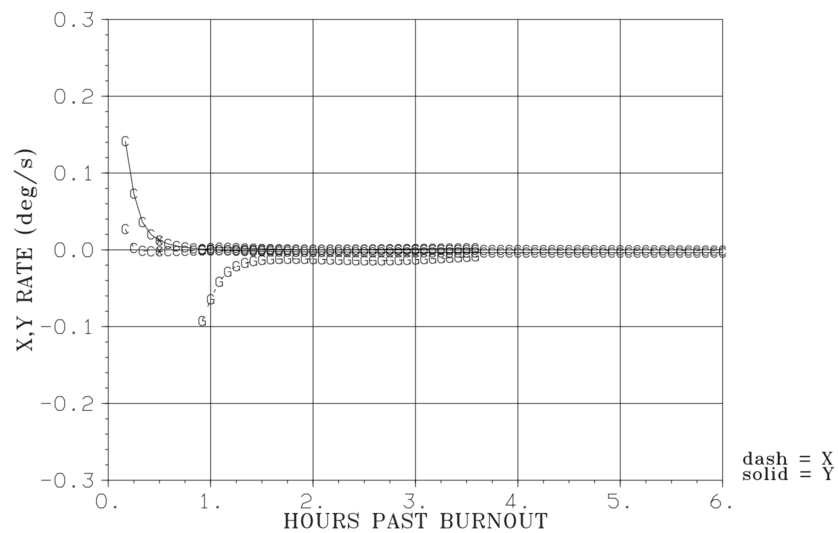
LAUNCH UTC 17:11:17
STAGE 3 BURNOUT 17:56:42
TRANSMIT 18:22:56

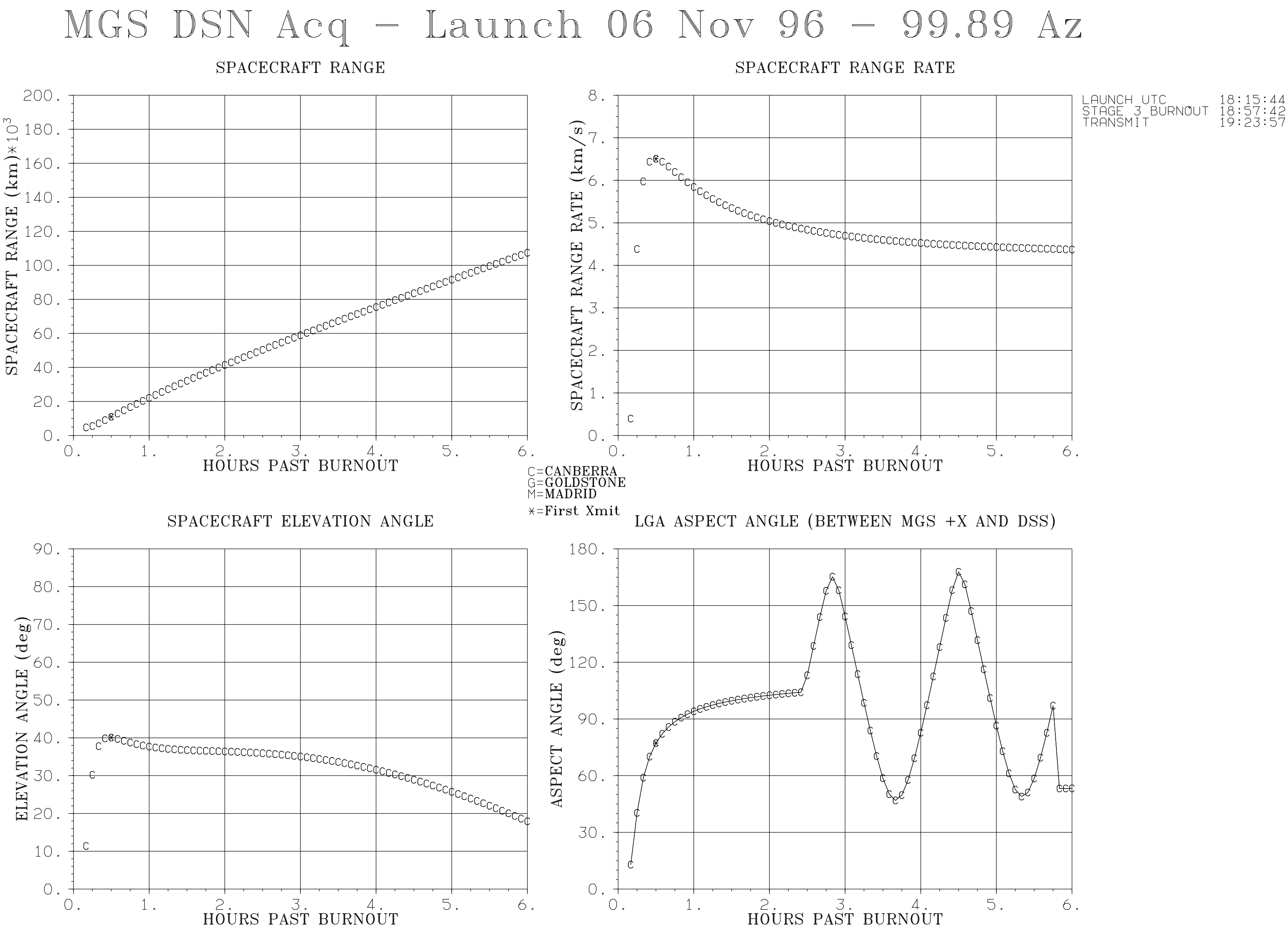
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)

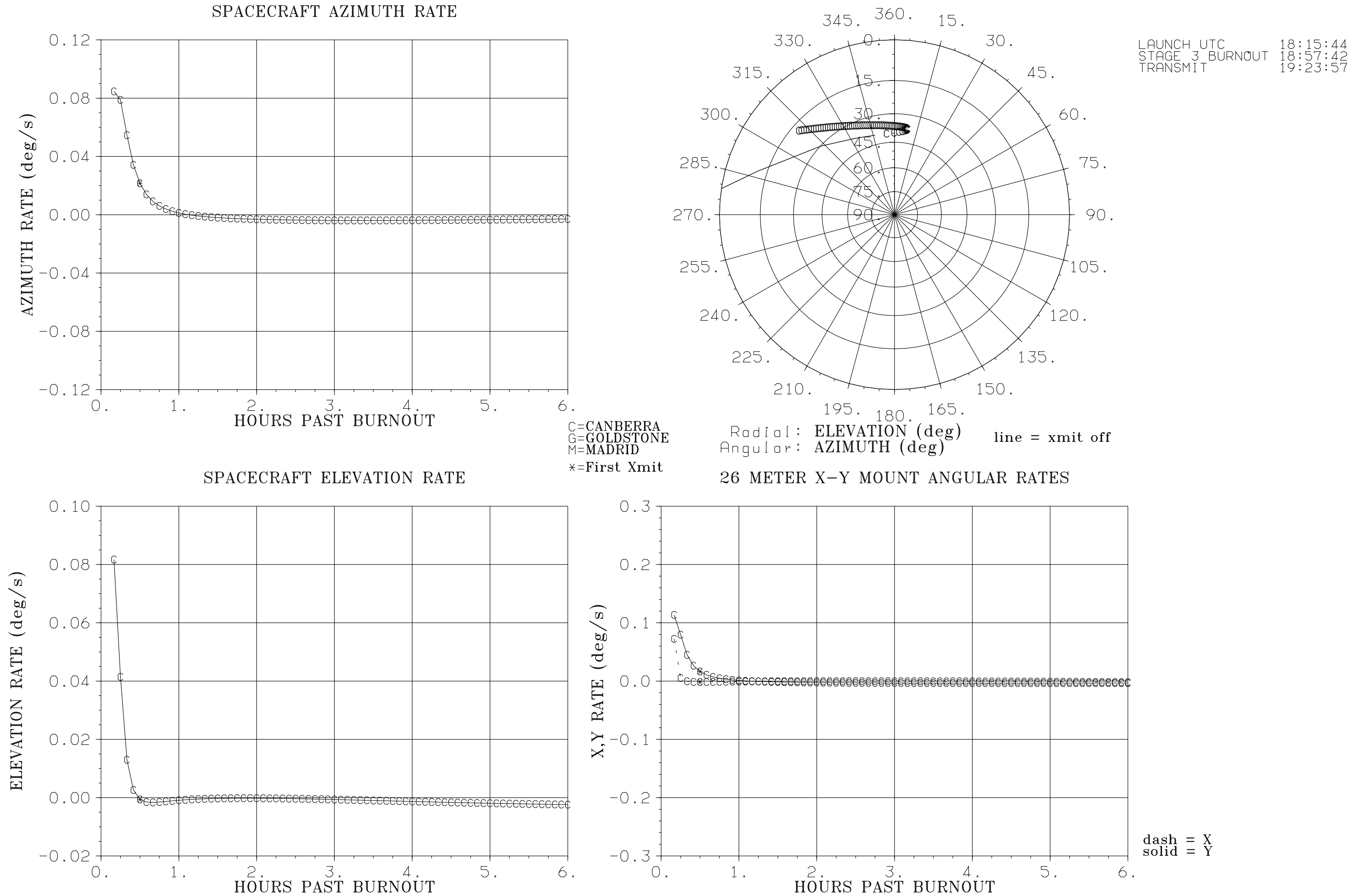
line = xmit off

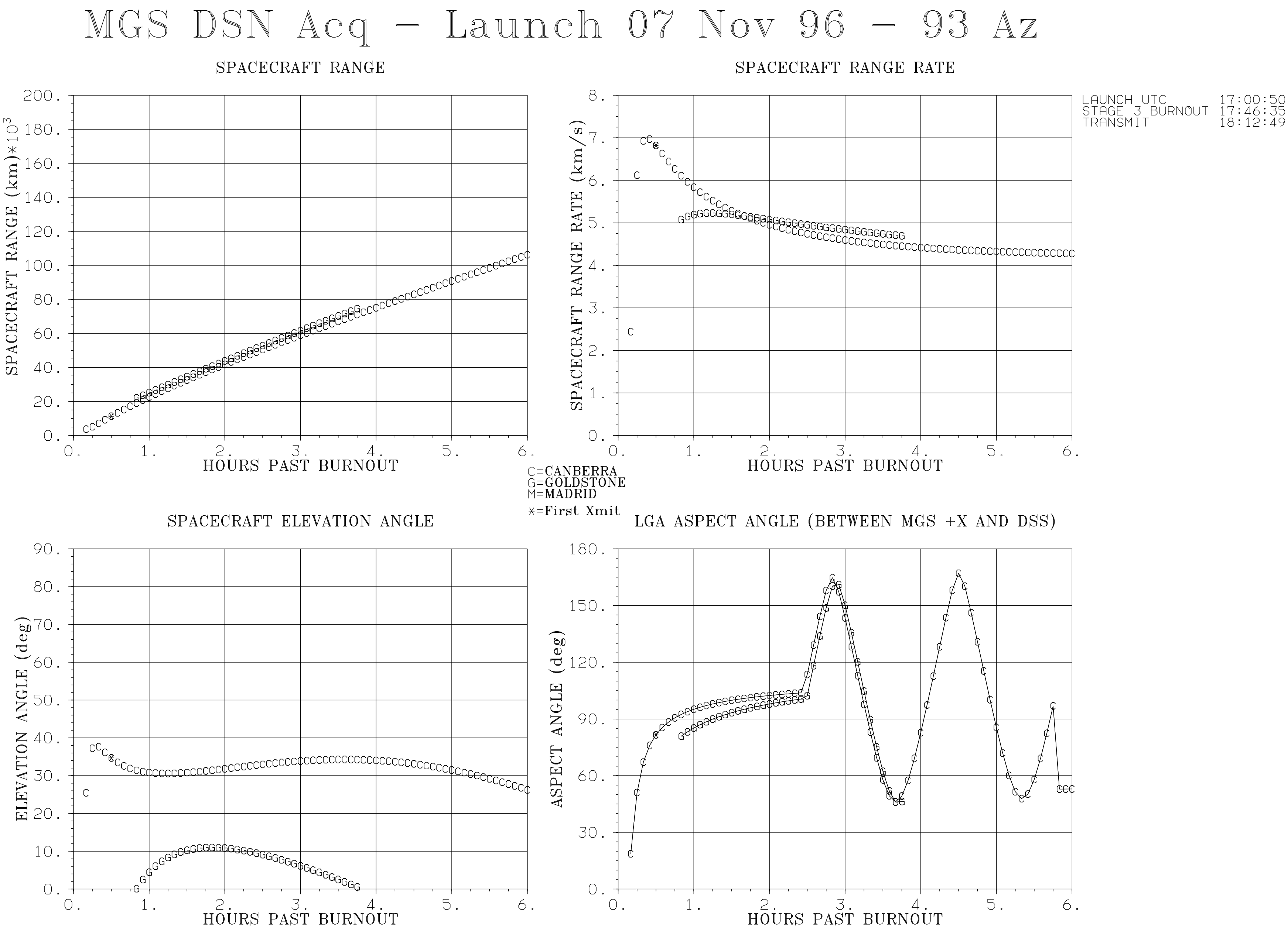




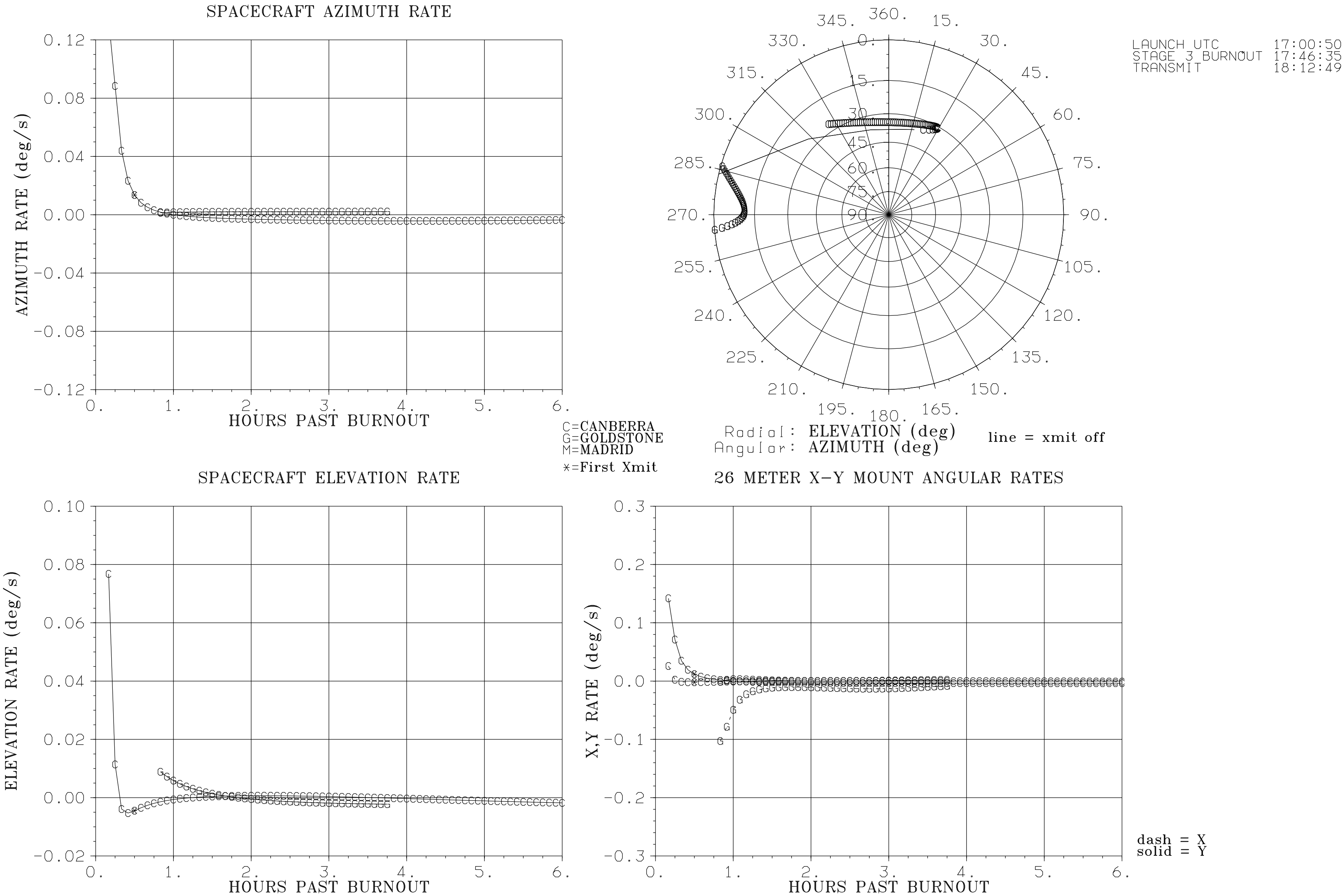

MGS DSN Acq - Launch 06 Nov 96 - 99.89 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
LAUNCH UTC 18:15:44
STAGE 3 BURNOUT 18:57:42
TRANSMIT 19:23:57
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)

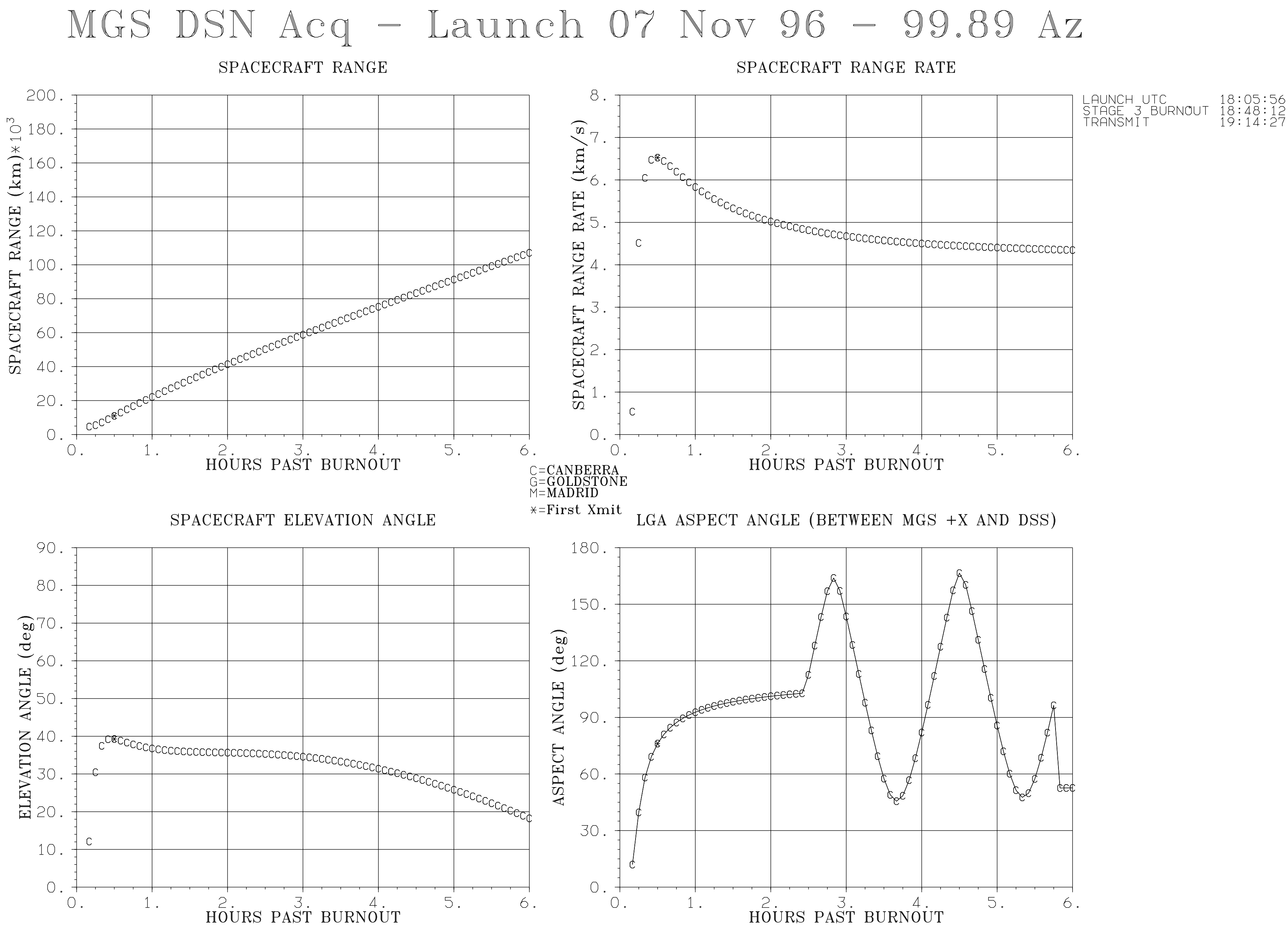
MGS DSN Acq - Launch 06 Nov 96 - 99.89 Az




MGS DSN Acq - Launch 07 Nov 96 - 93 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 17:00:50
STAGE 3 BURNOUT 17:46:35
TRANSMIT 18:12:49
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

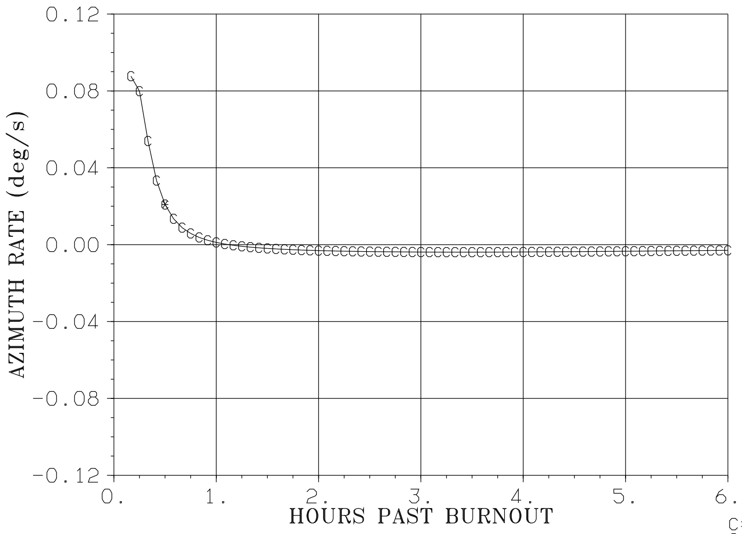
MGS DSN Acq - Launch 07 Nov 96 - 93 Az

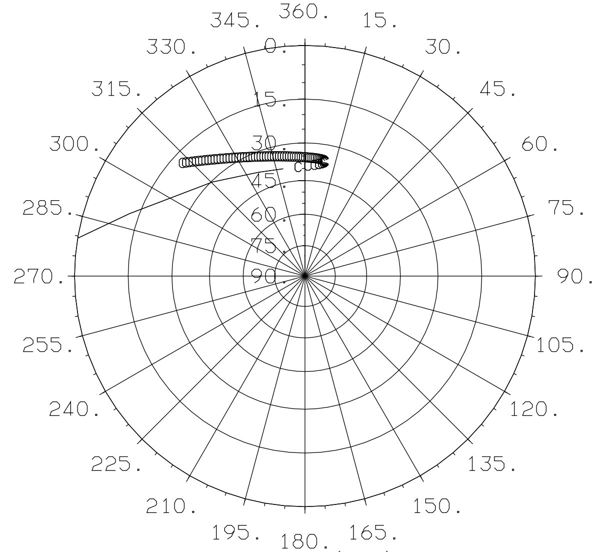



MGS DSN Acq - Launch 07 Nov 96 - 99.89 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 18:05:56
STAGE 3 BURNOUT 18:48:12
TRANSMIT 19:14:27
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

MGS DSN Acq - Launch 07 Nov 96 - 99.89 Az

SPACECRAFT AZIMUTH RATE





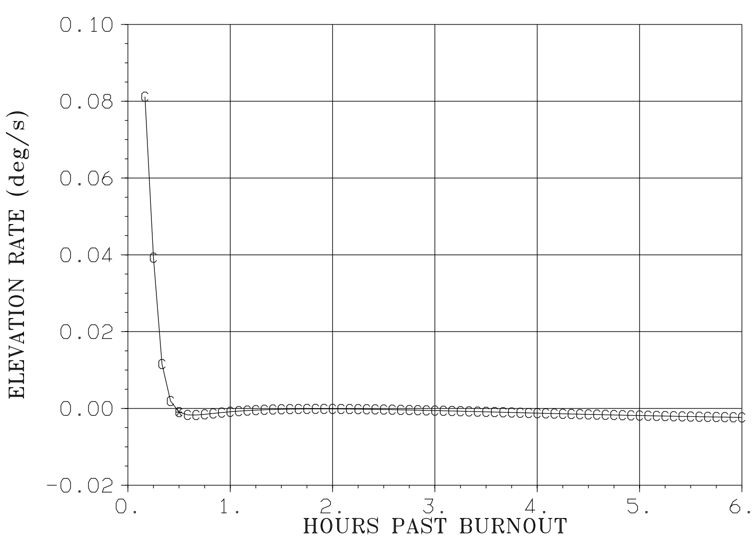
LAUNCH UTC 18:05:56
STAGE 3 BURNOUT 18:48:12
TRANSMIT 19:14:27

C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

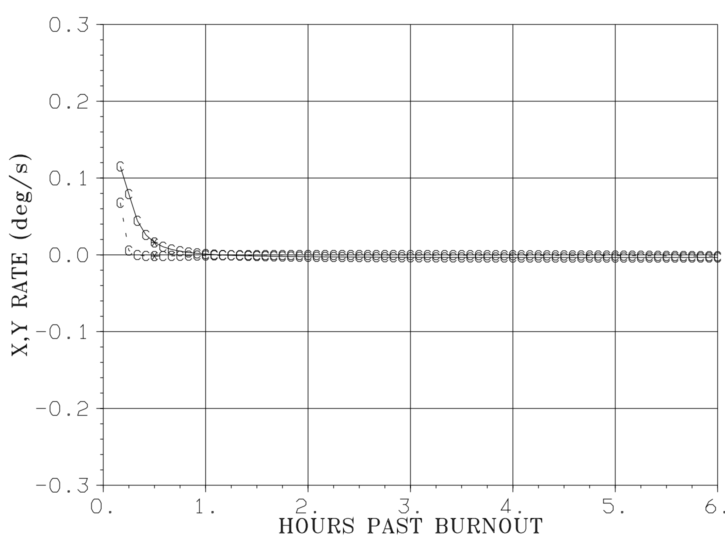
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)

line = xmit off

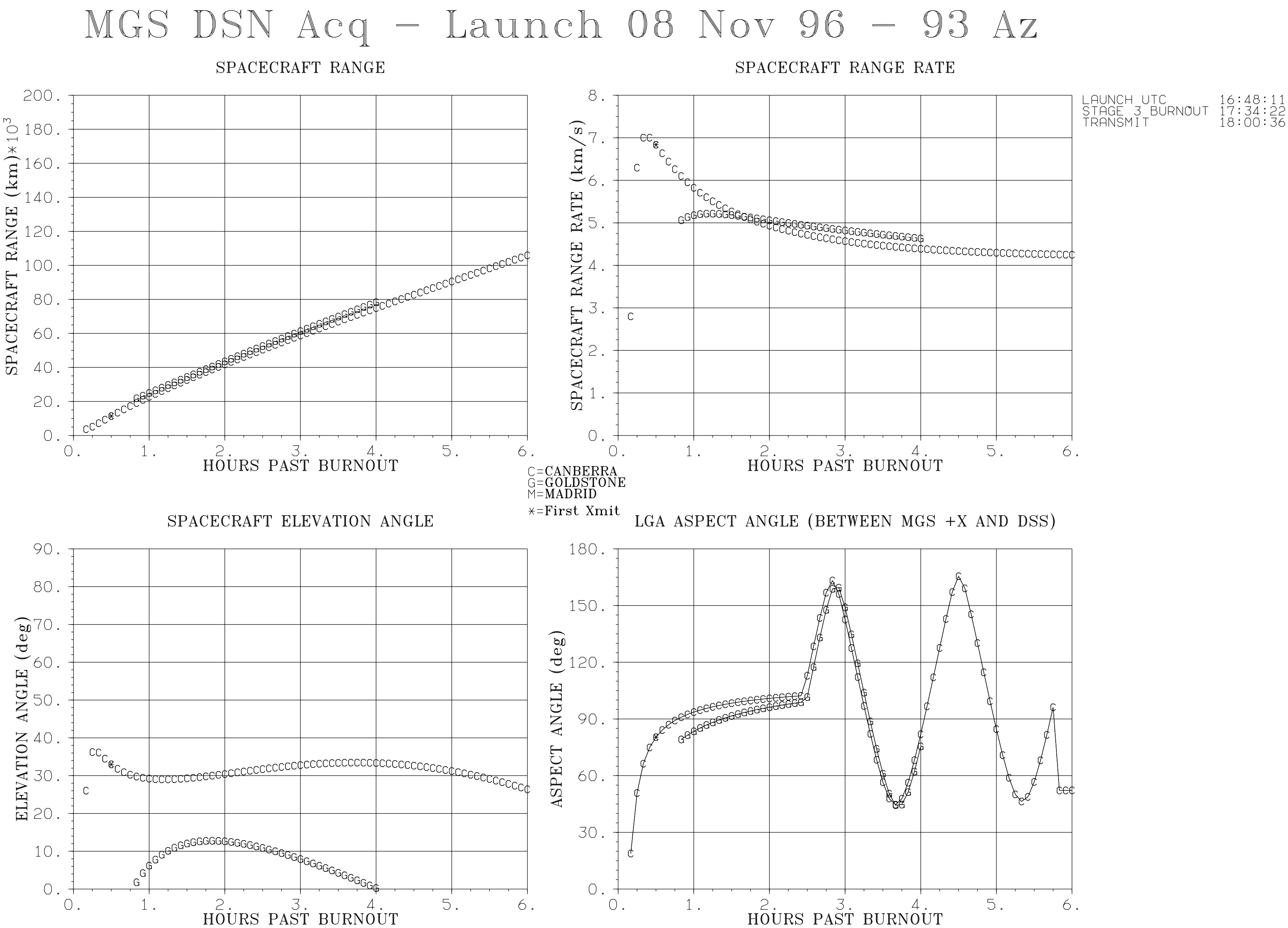
SPACECRAFT ELEVATION RATE



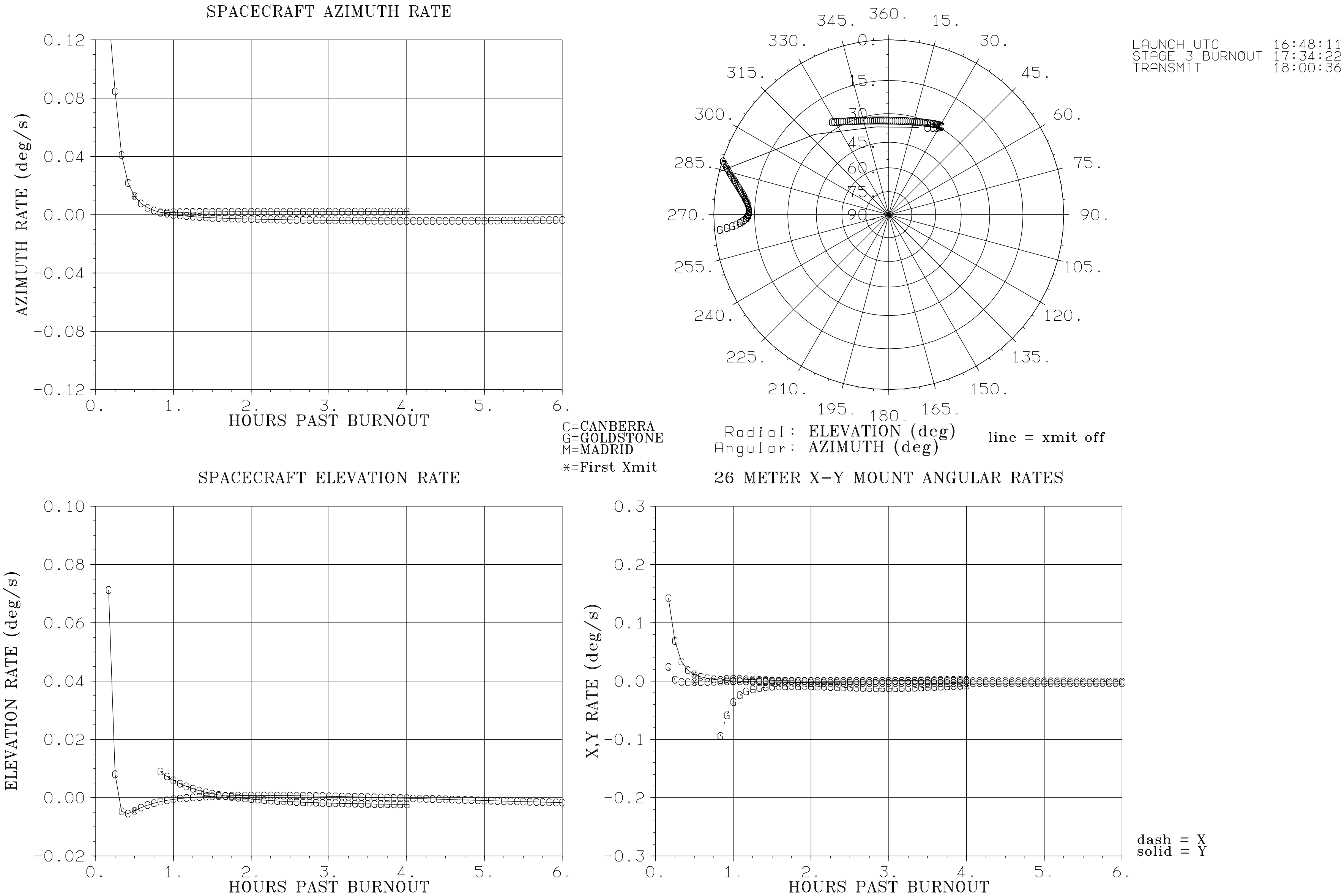
26 METER X-Y MOUNT ANGULAR RATES



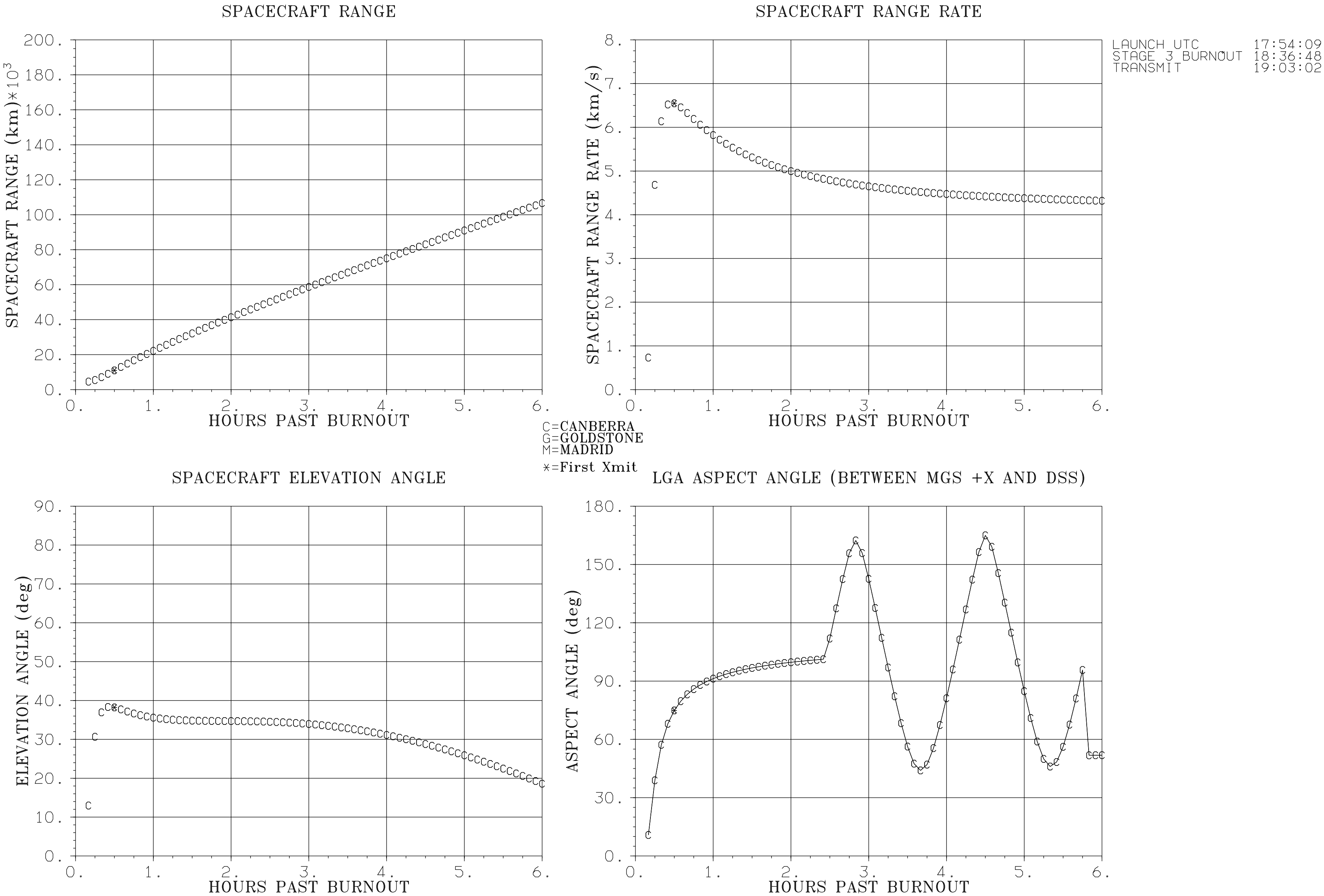
dash = X
solid = Y


MGS DSN Acq - Launch 08 Nov 96 - 93 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
LAUNCH UTC 16:48:11
STAGE 3 BURNOUT 17:34:22
TRANSMIT 18:00:36
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)

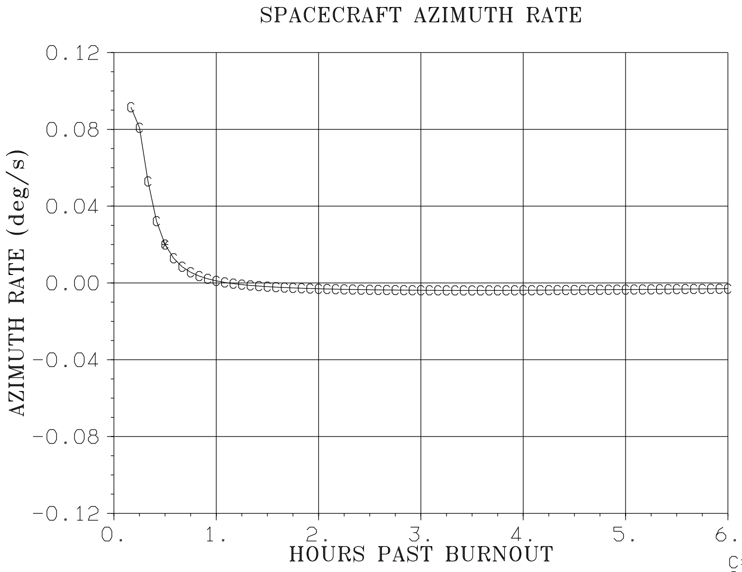
MGS DSN Acq - Launch 08 Nov 96 - 93 Az

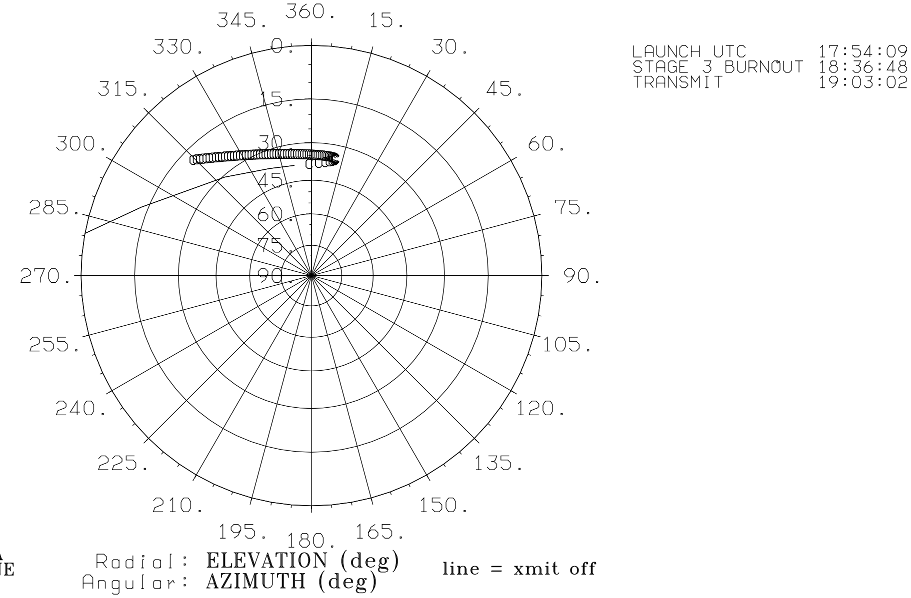


MGS DSN Acq – Launch 08 Nov 96 – 99.89 Az

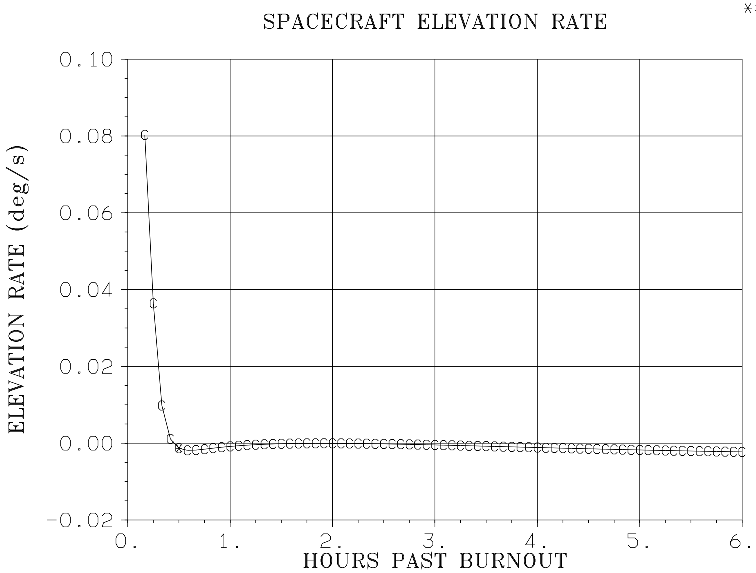


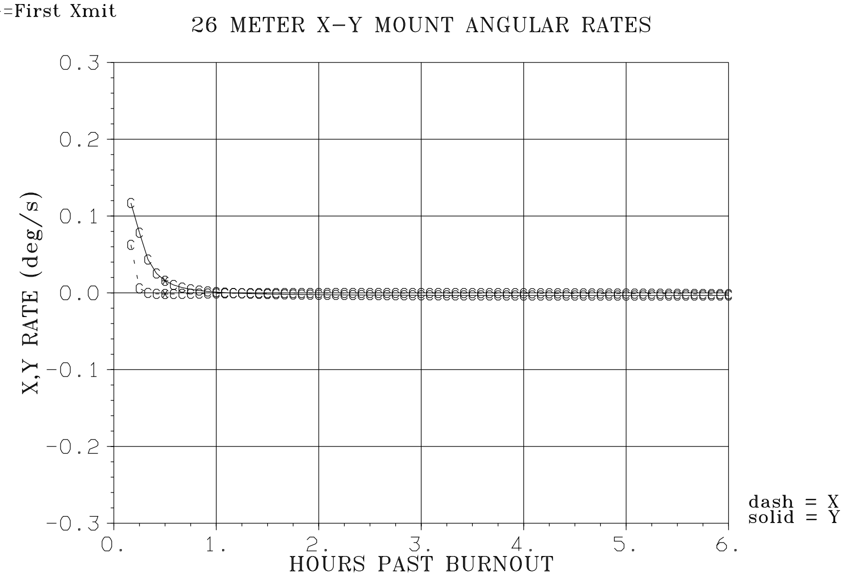
MGS DSN Acq – Launch 08 Nov 96 – 99.89 Az



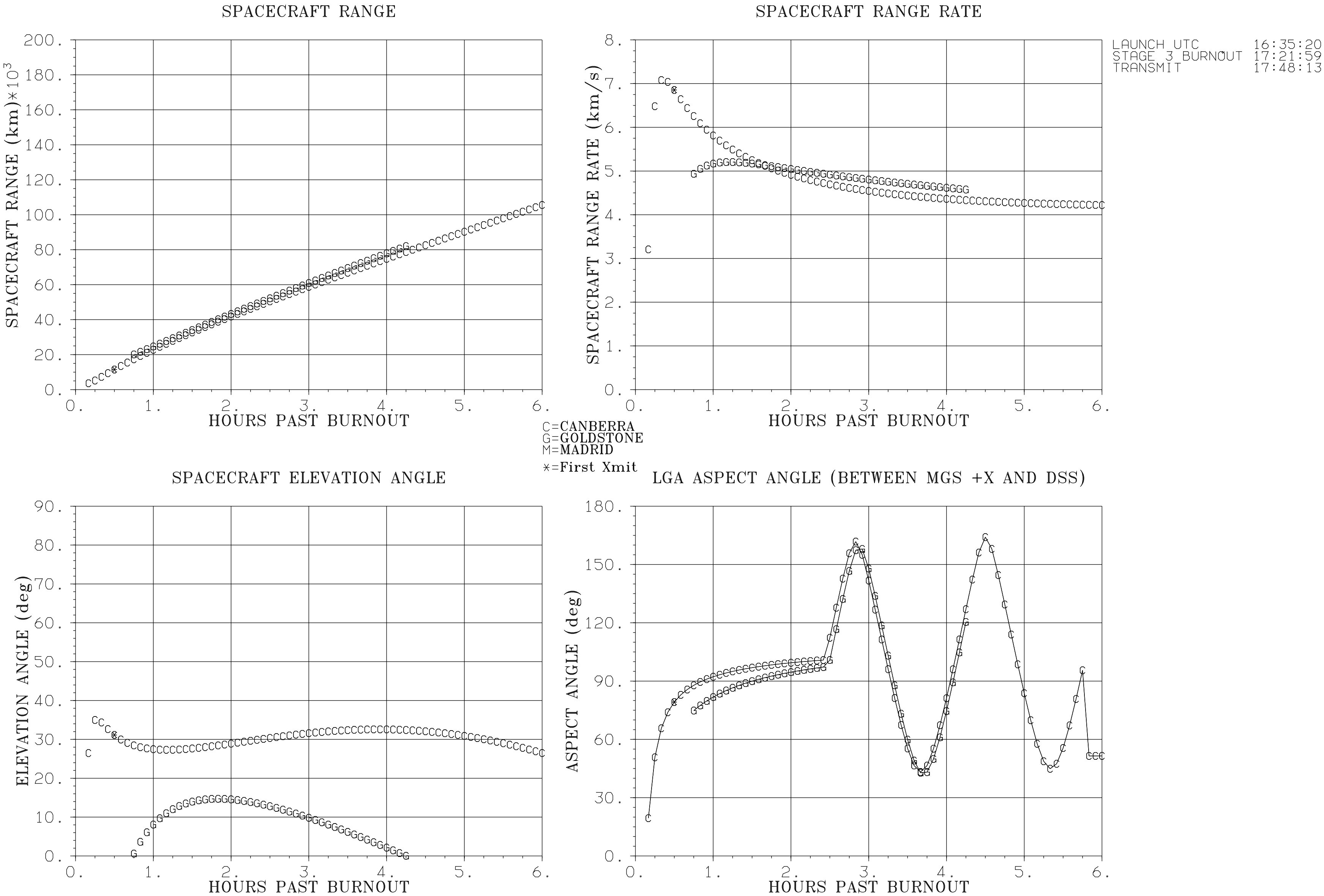


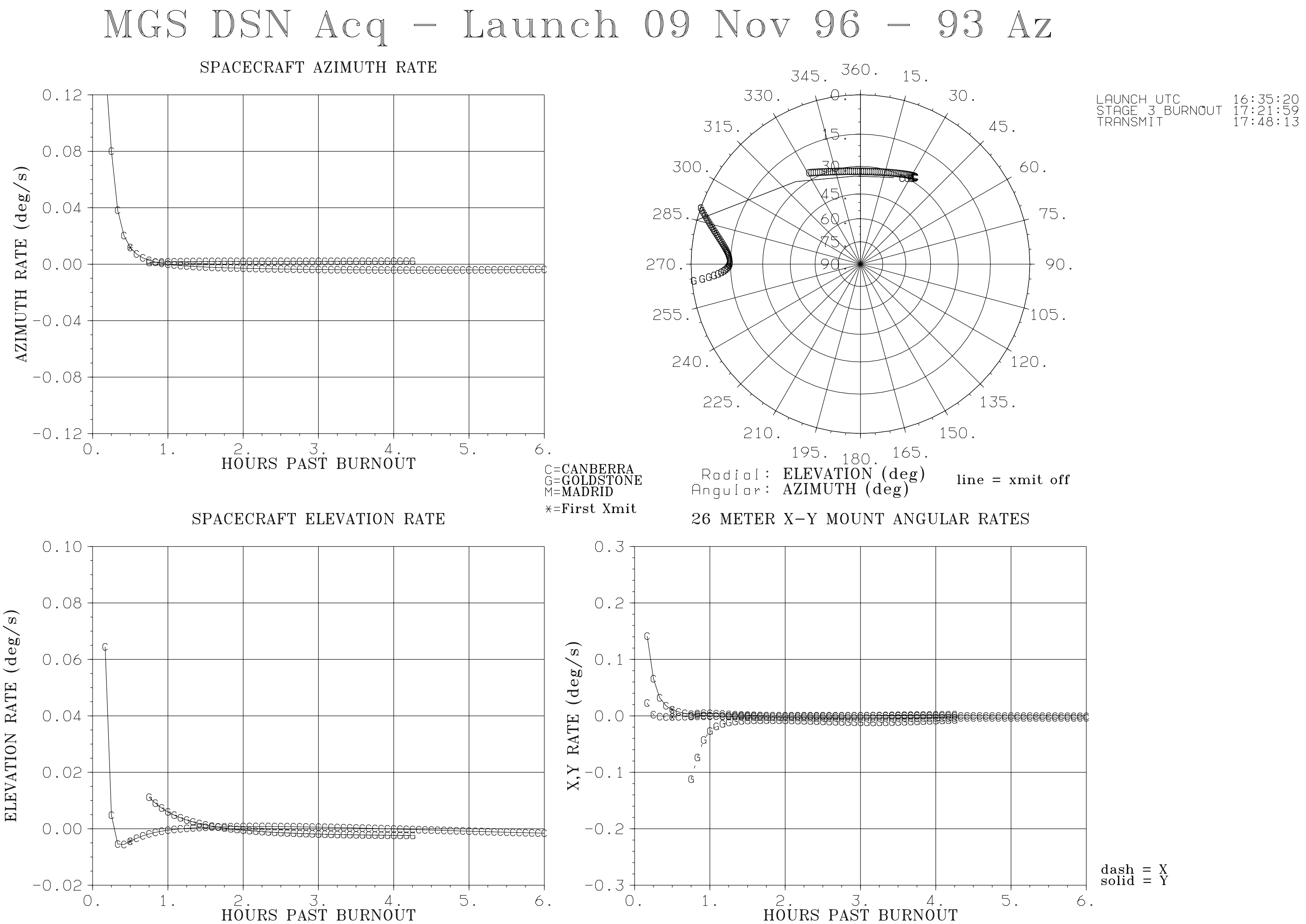
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

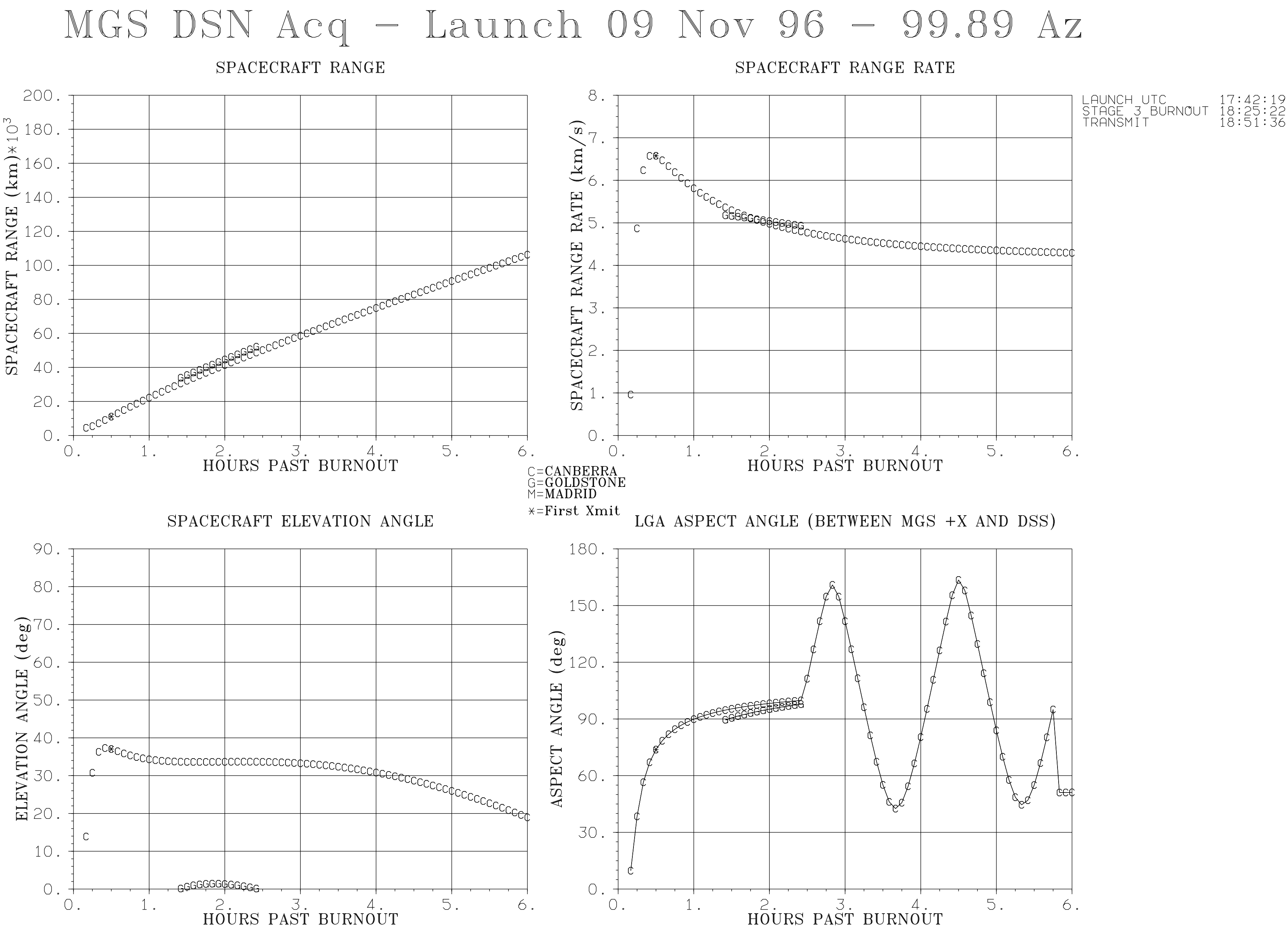




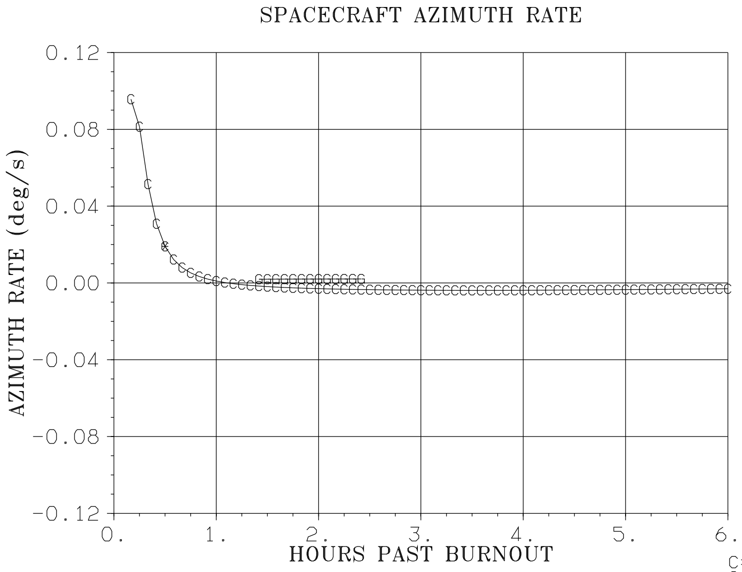
MGS DSN Acq - Launch 09 Nov 96 - 93 Az

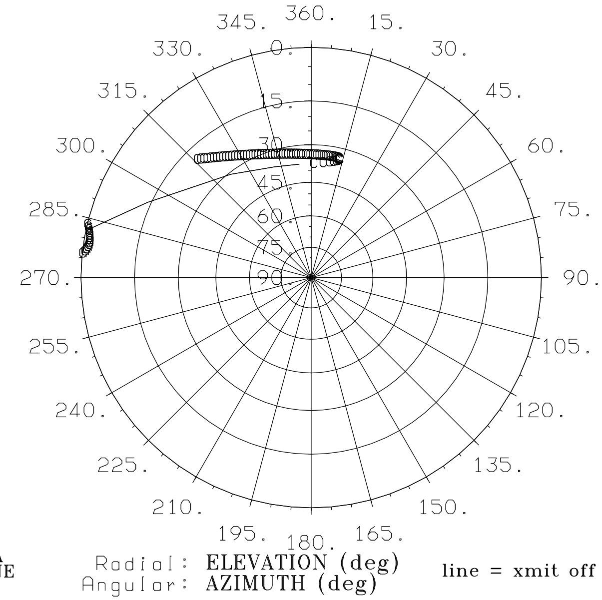



MGS DSN Acq - Launch 09 Nov 96 - 93 Az
SPACECRAFT AZIMUTH RATE
AZIMUTH RATE (deg/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:35:20
STAGE 3 BURNOUT 17:21:59
TRANSMIT 17:48:13
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)
line = xmit off
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION RATE
ELEVATION RATE (deg/s)
HOURS PAST BURNOUT
26 METER X-Y MOUNT ANGULAR RATES
X,Y RATE (deg/s)
HOURS PAST BURNOUT
dash = X
solid = Y


MGS DSN Acq - Launch 09 Nov 96 - 99.89 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 17:42:19
STAGE 3 BURNOUT 18:25:22
TRANSMIT 18:51:36
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

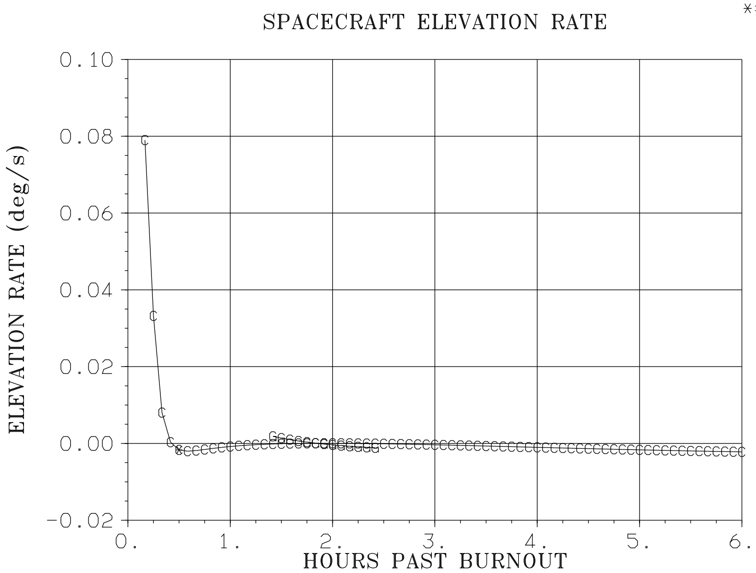
MGS DSN Acq - Launch 09 Nov 96 - 99.89 Az

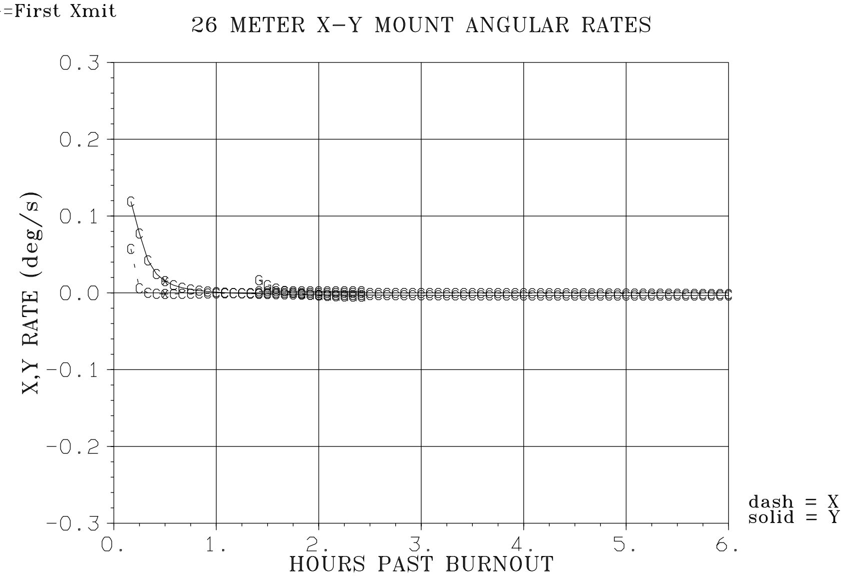


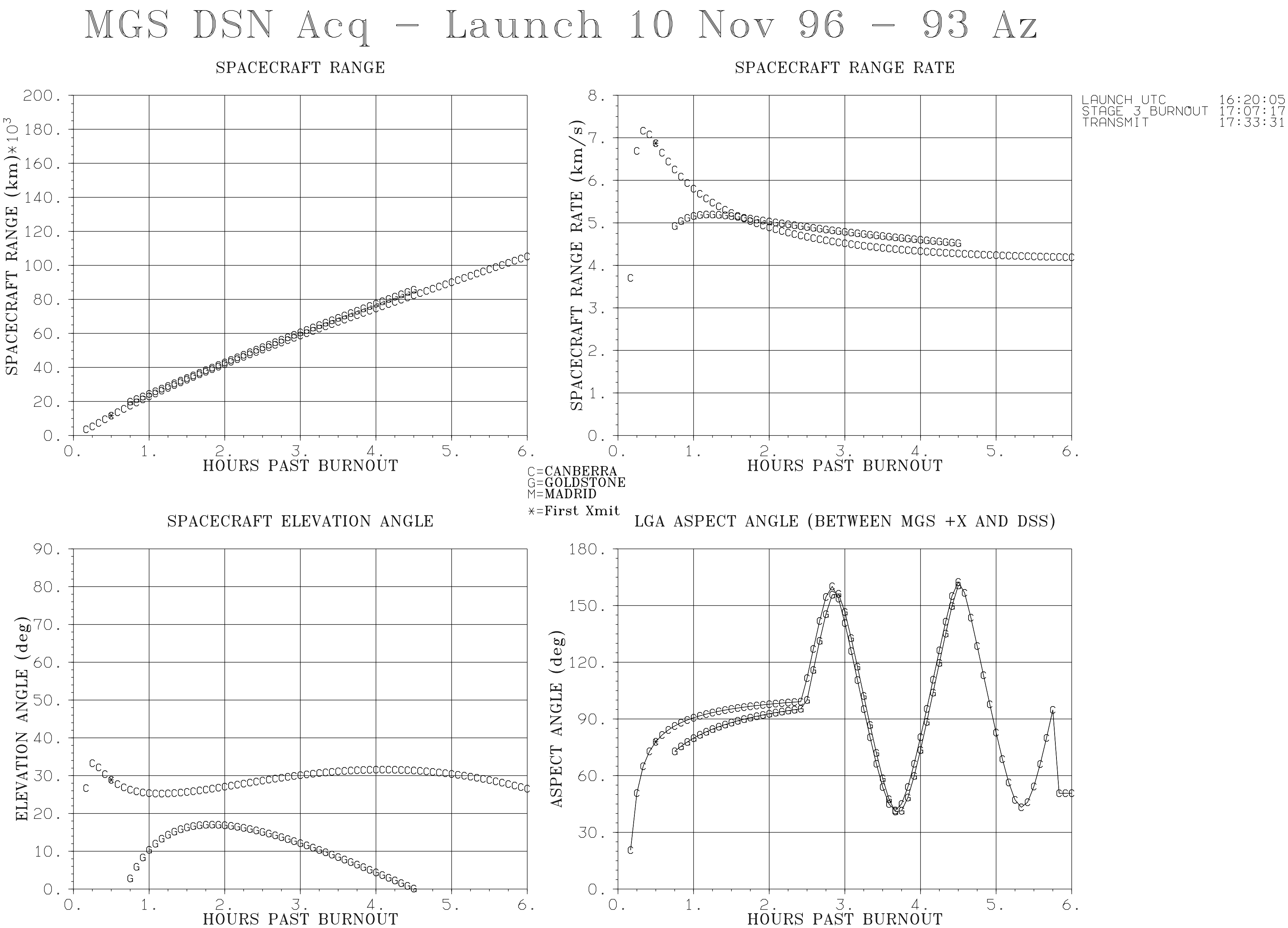


LAUNCH UTC 17:42:19
STAGE 3 BURNOUT 18:25:22
TRANSMIT 18:51:36

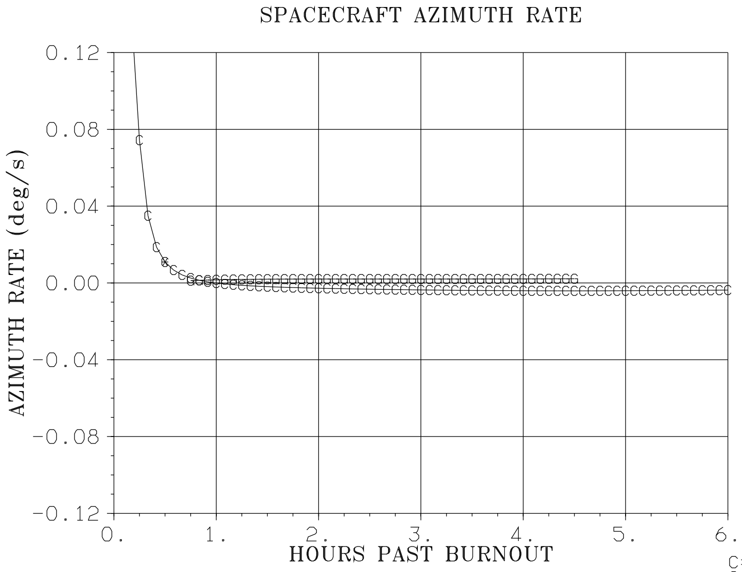
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

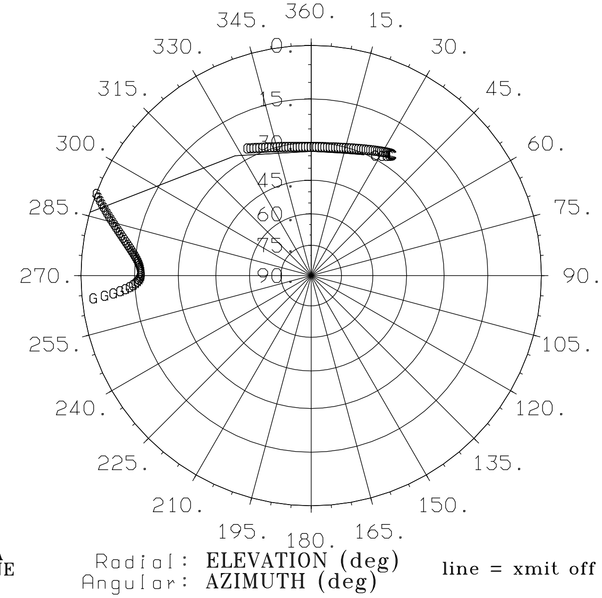





MGS DSN Acq - Launch 10 Nov 96 - 93 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:20:05
STAGE 3 BURNOUT 17:07:17
TRANSMIT 17:33:31
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

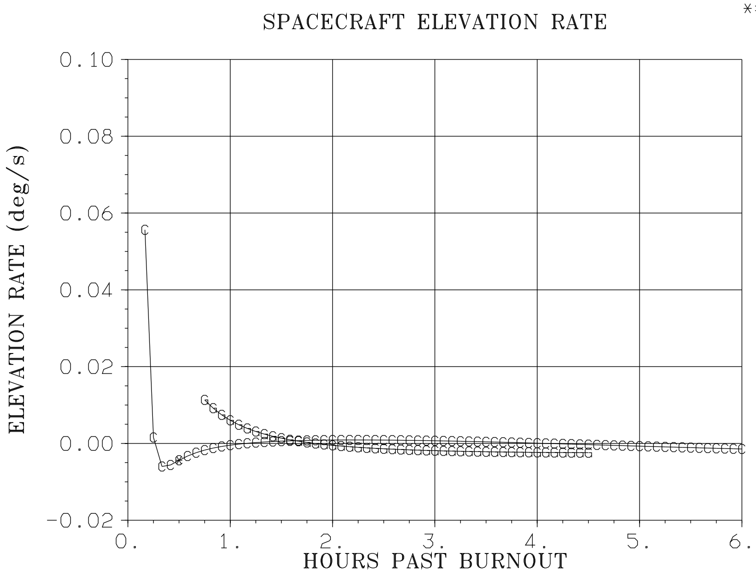
MGS DSN Acq – Launch 10 Nov 96 – 93 Az

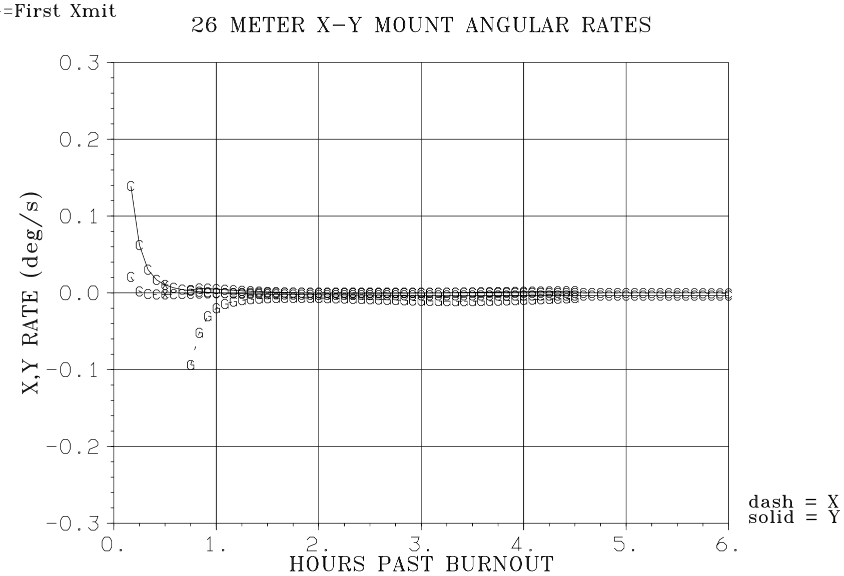




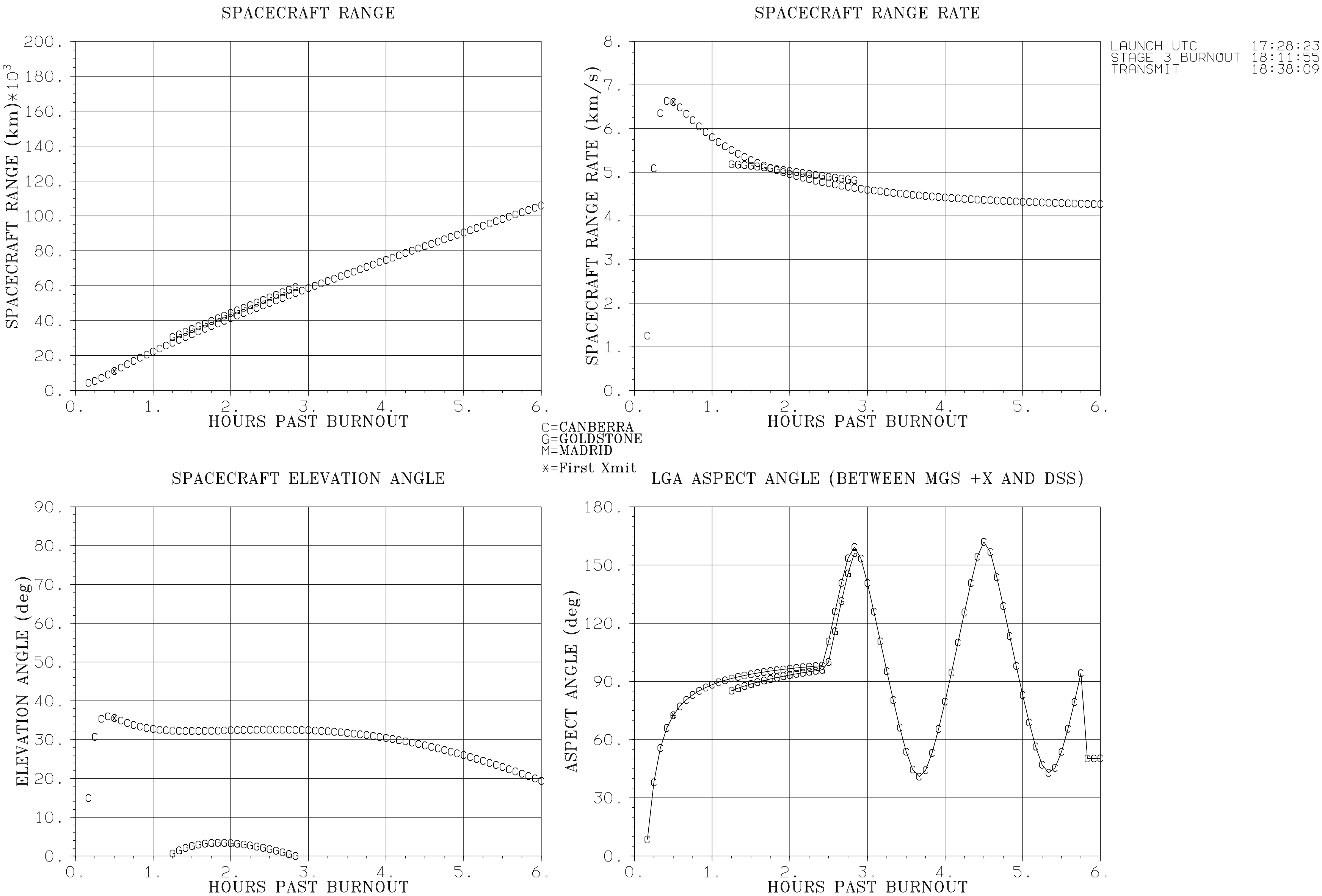
LAUNCH UTC 16:20:05
STAGE 3 BURNOUT 17:07:17
TRANSMIT 17:33:31

C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

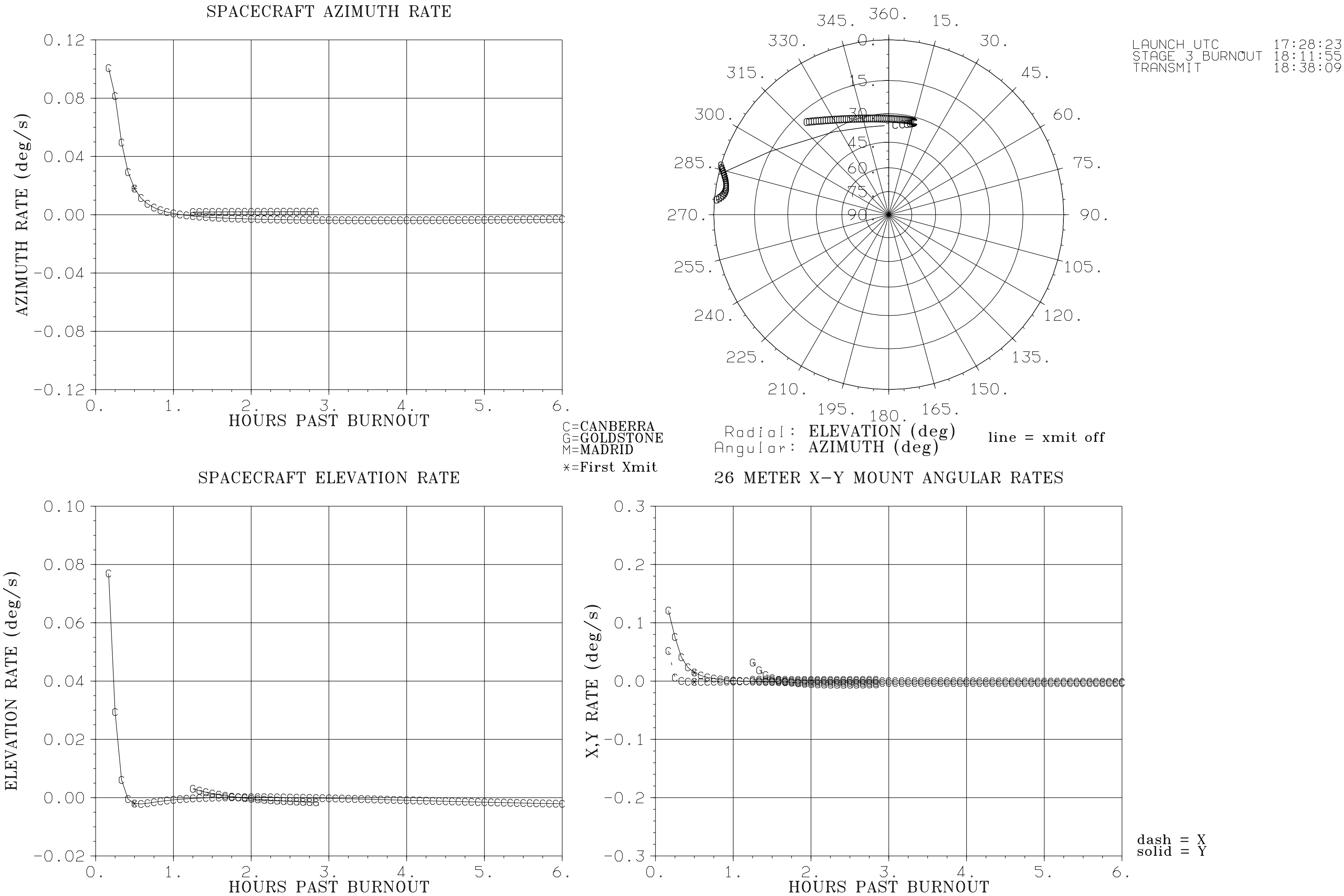


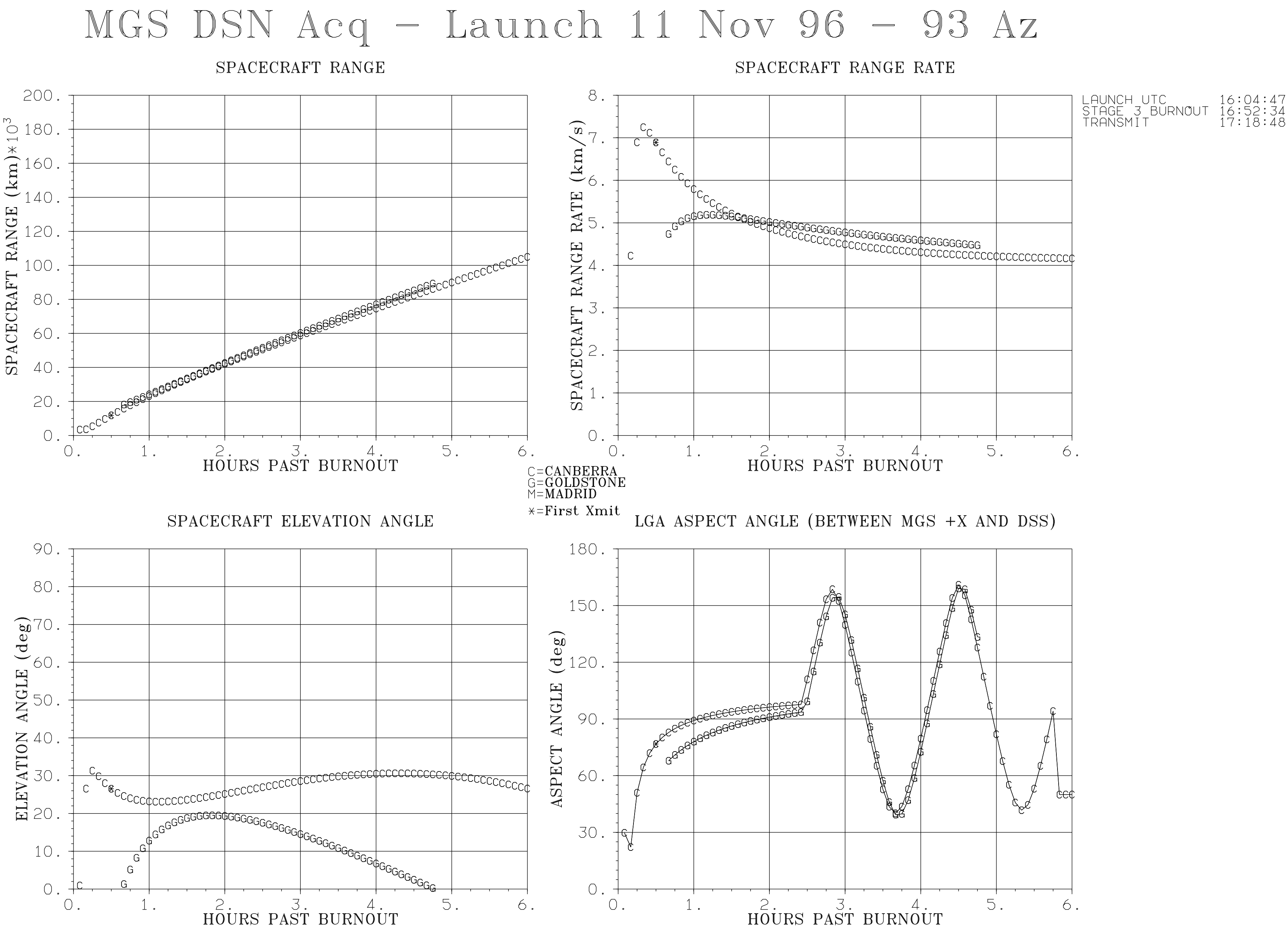


MGS DSN Acq - Launch 10 Nov 96 - 99.89 Az

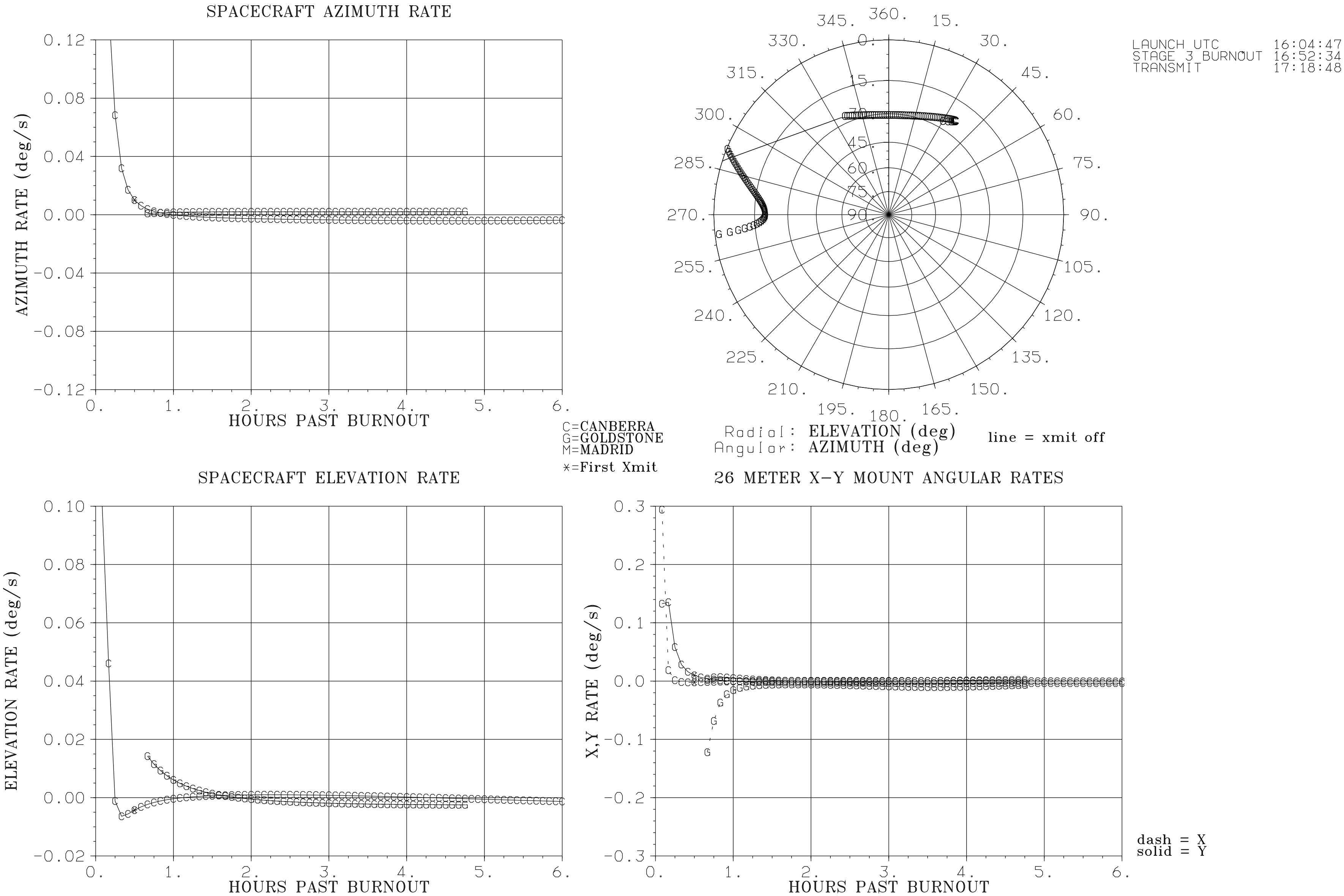


MGS DSN Acq - Launch 10 Nov 96 - 99.89 Az

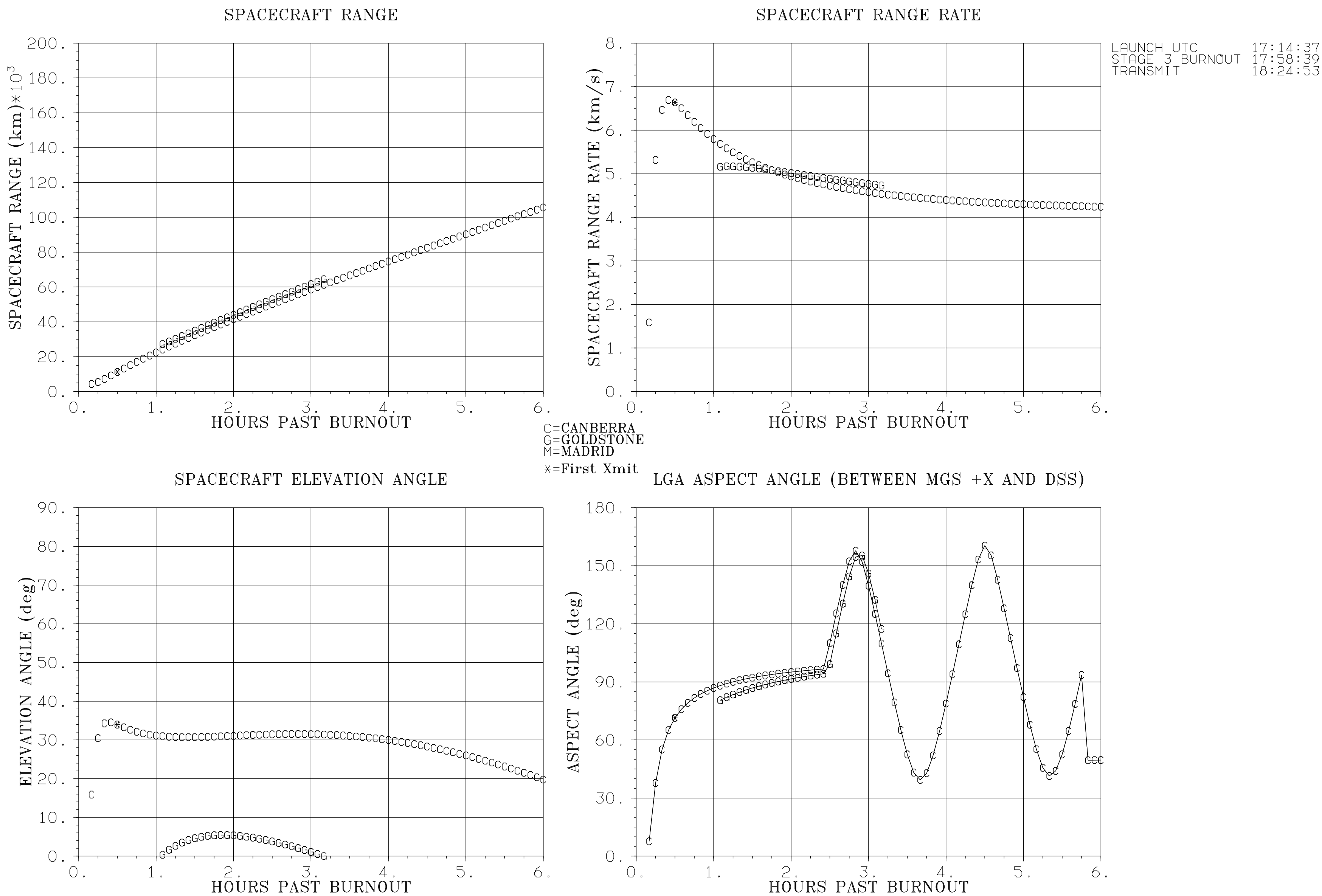



MGS DSN Acq - Launch 11 Nov 96 - 93 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:04:47
STAGE 3 BURNOUT 16:52:34
TRANSMIT 17:18:48
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

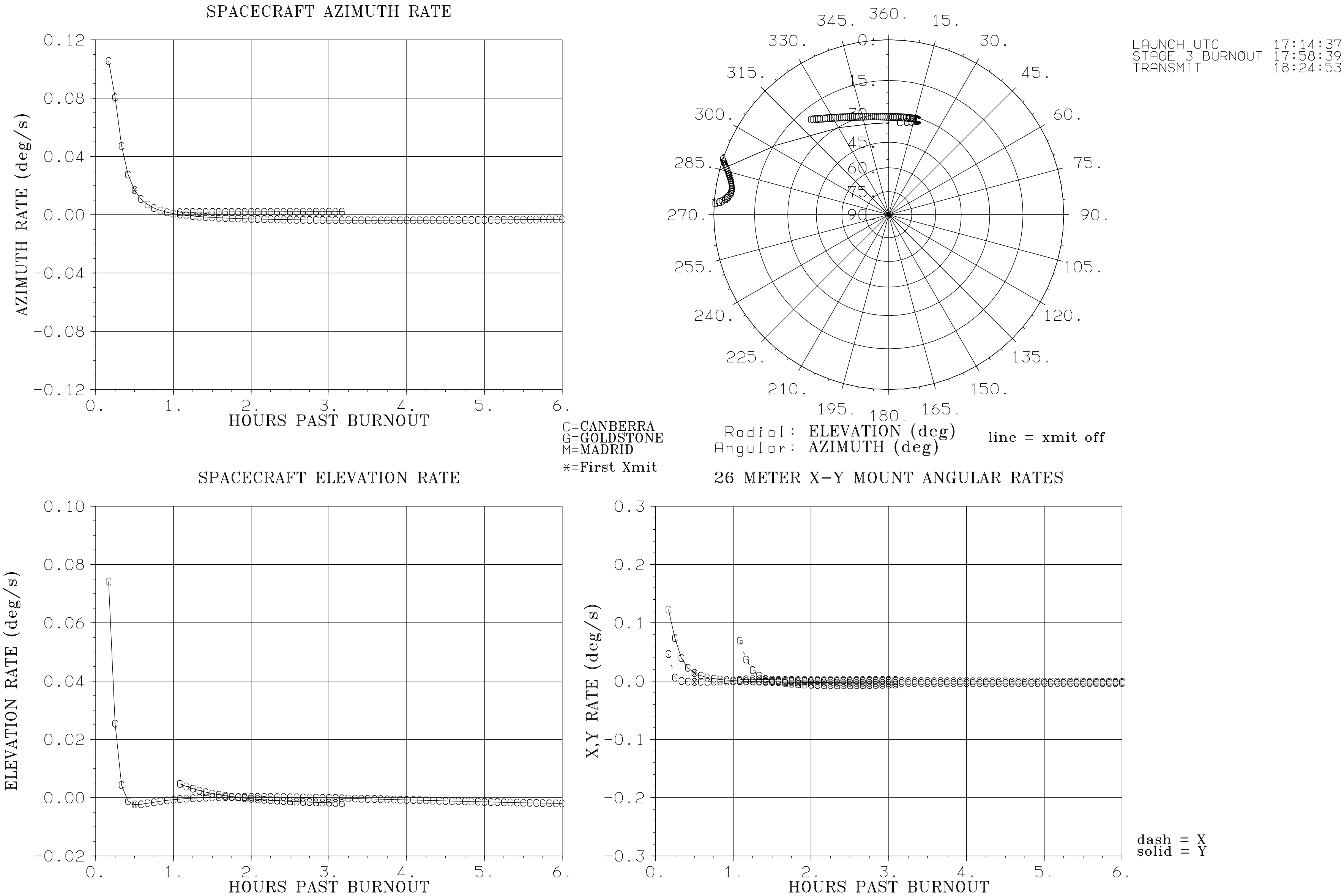
MGS DSN Acq - Launch 11 Nov 96 - 93 Az

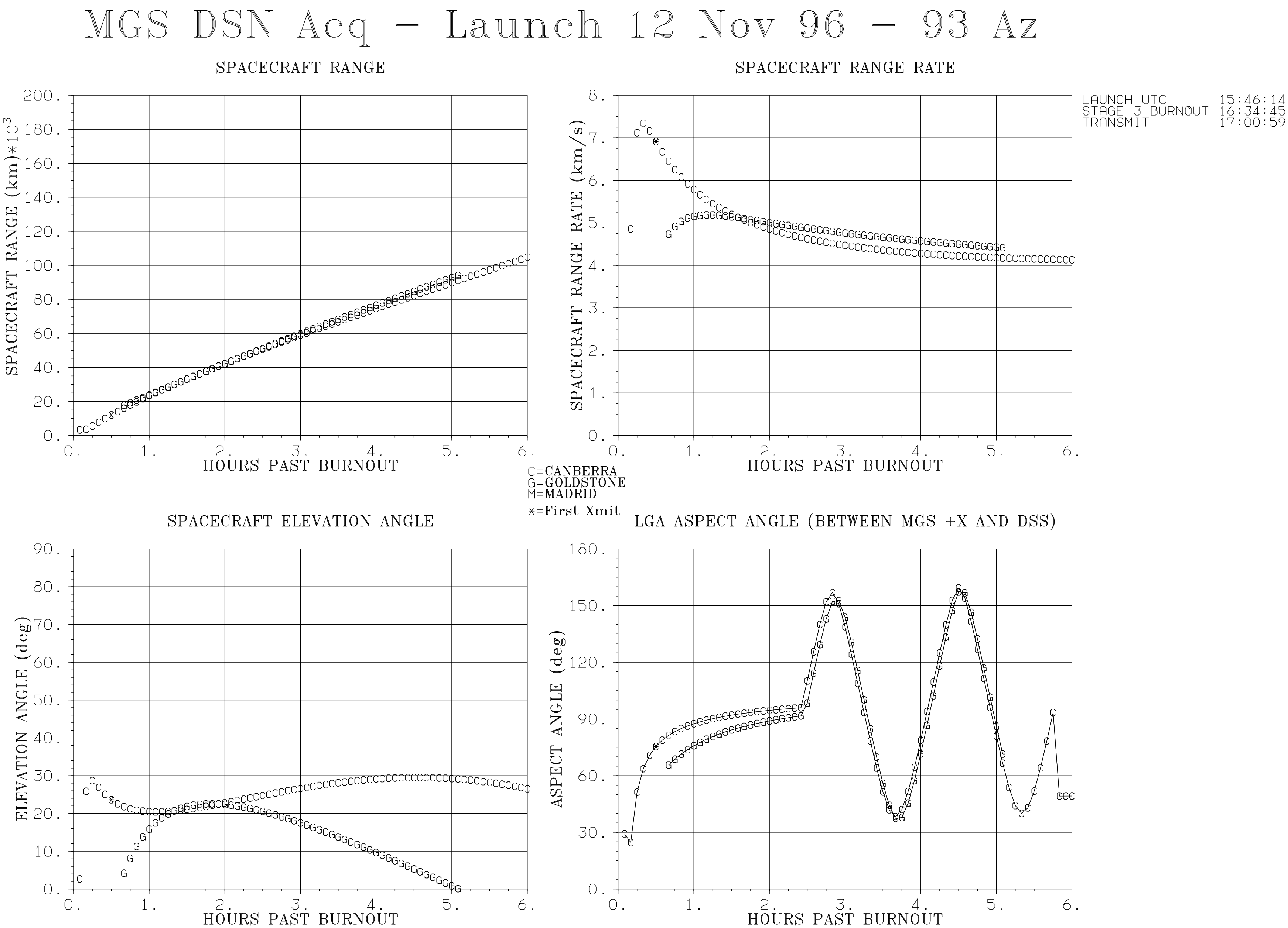


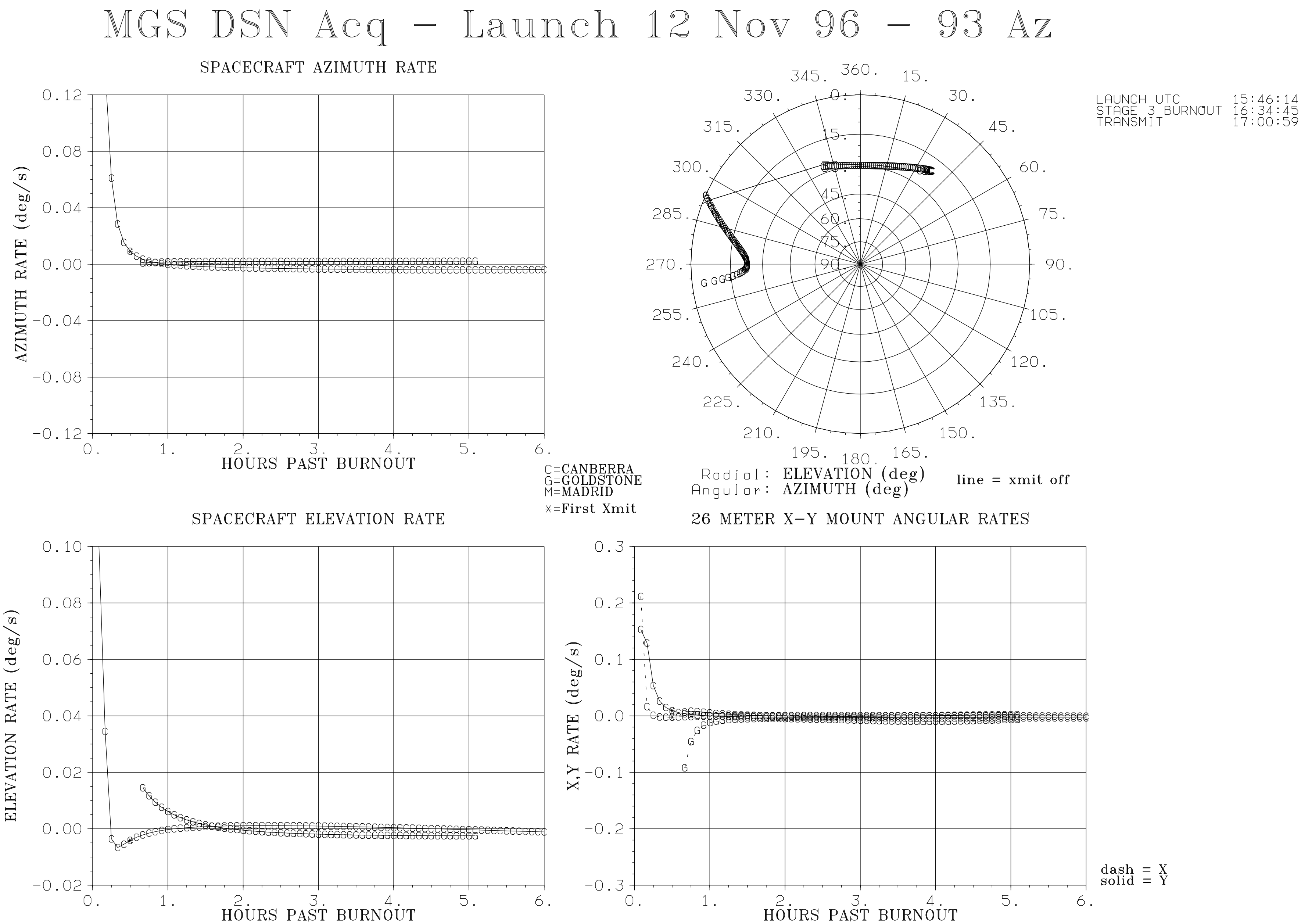
MGS DSN Acq - Launch 11 Nov 96 - 99.89 Az

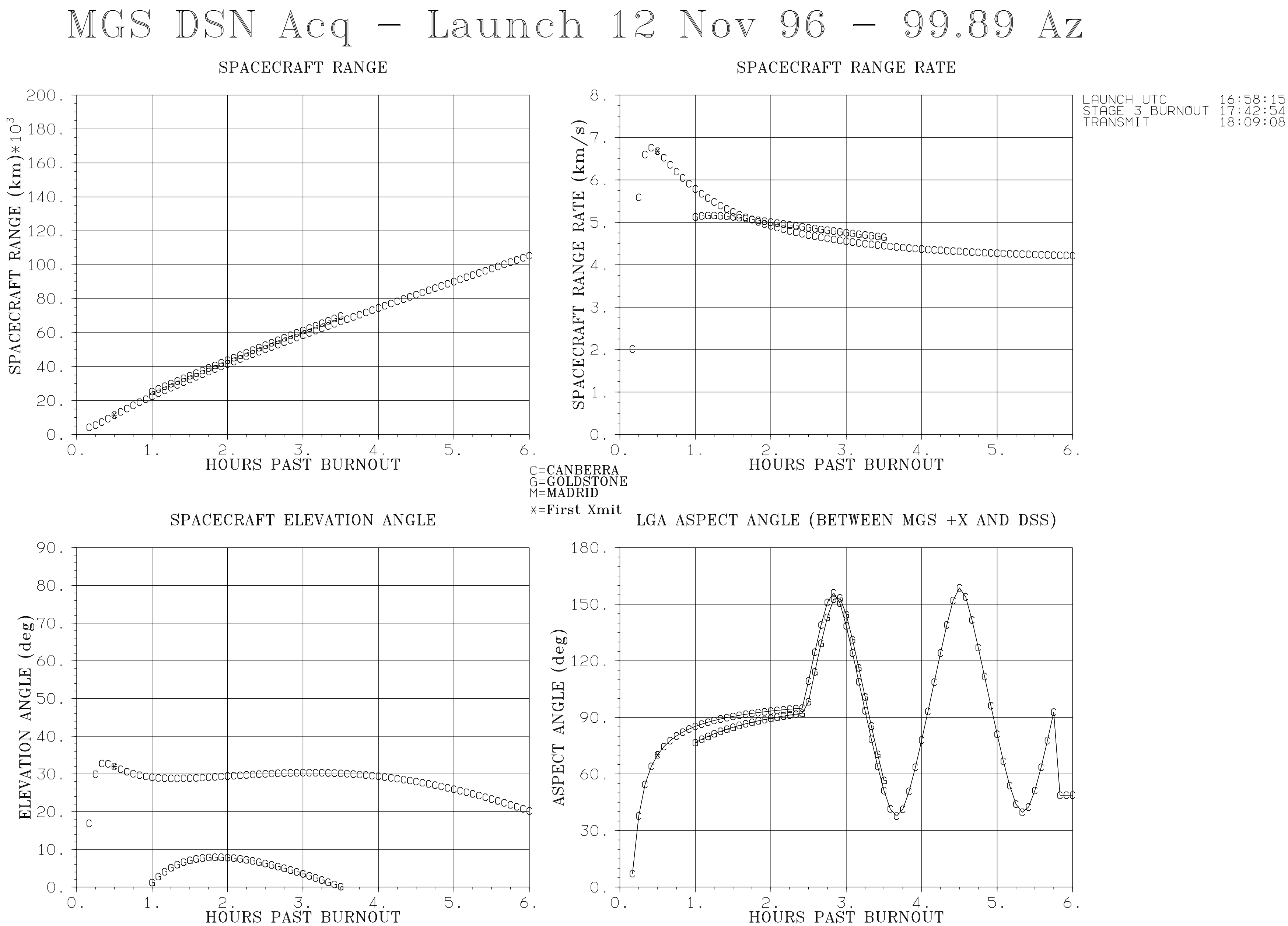


MGS DSN Acq - Launch 11 Nov 96 - 99.89 Az

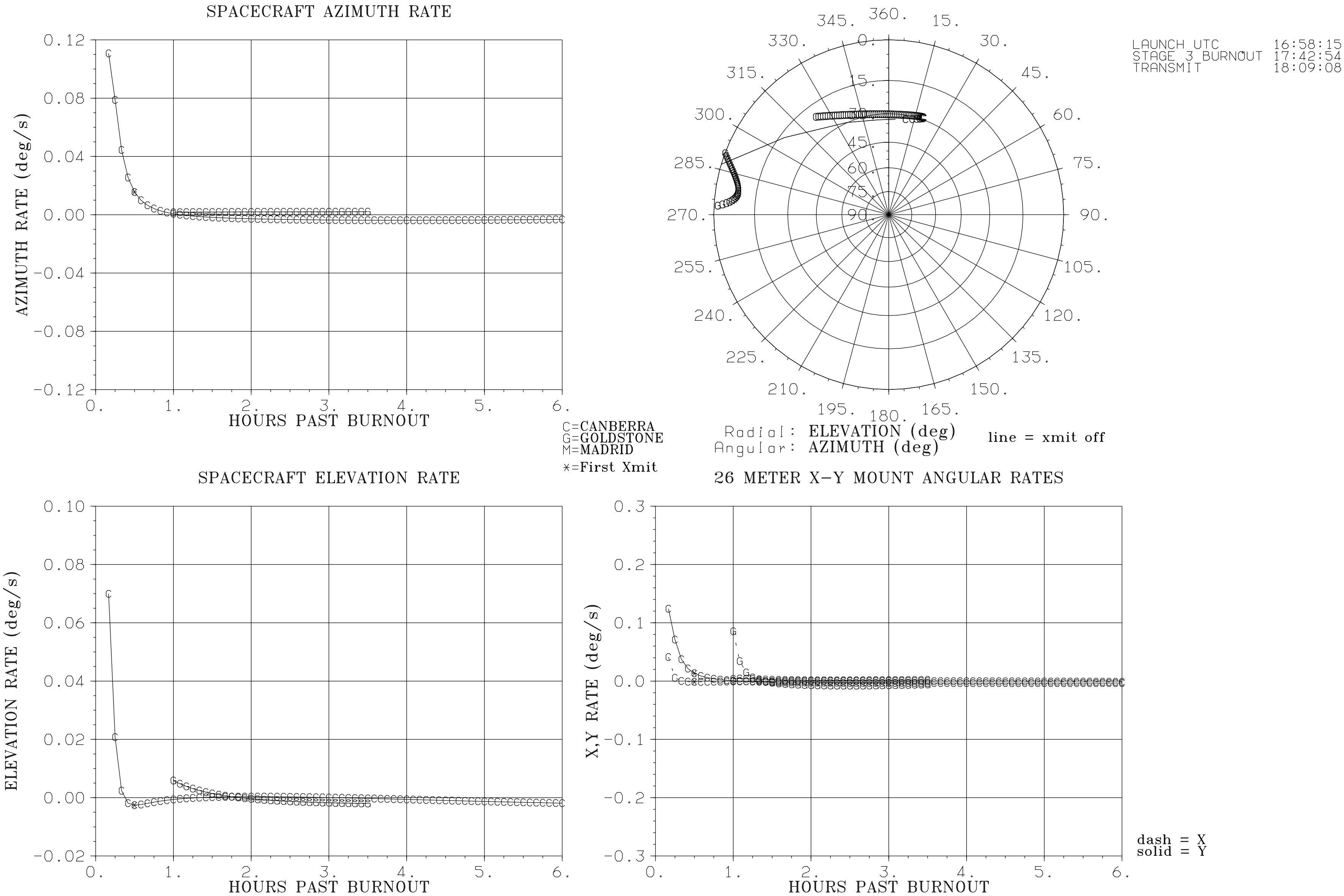


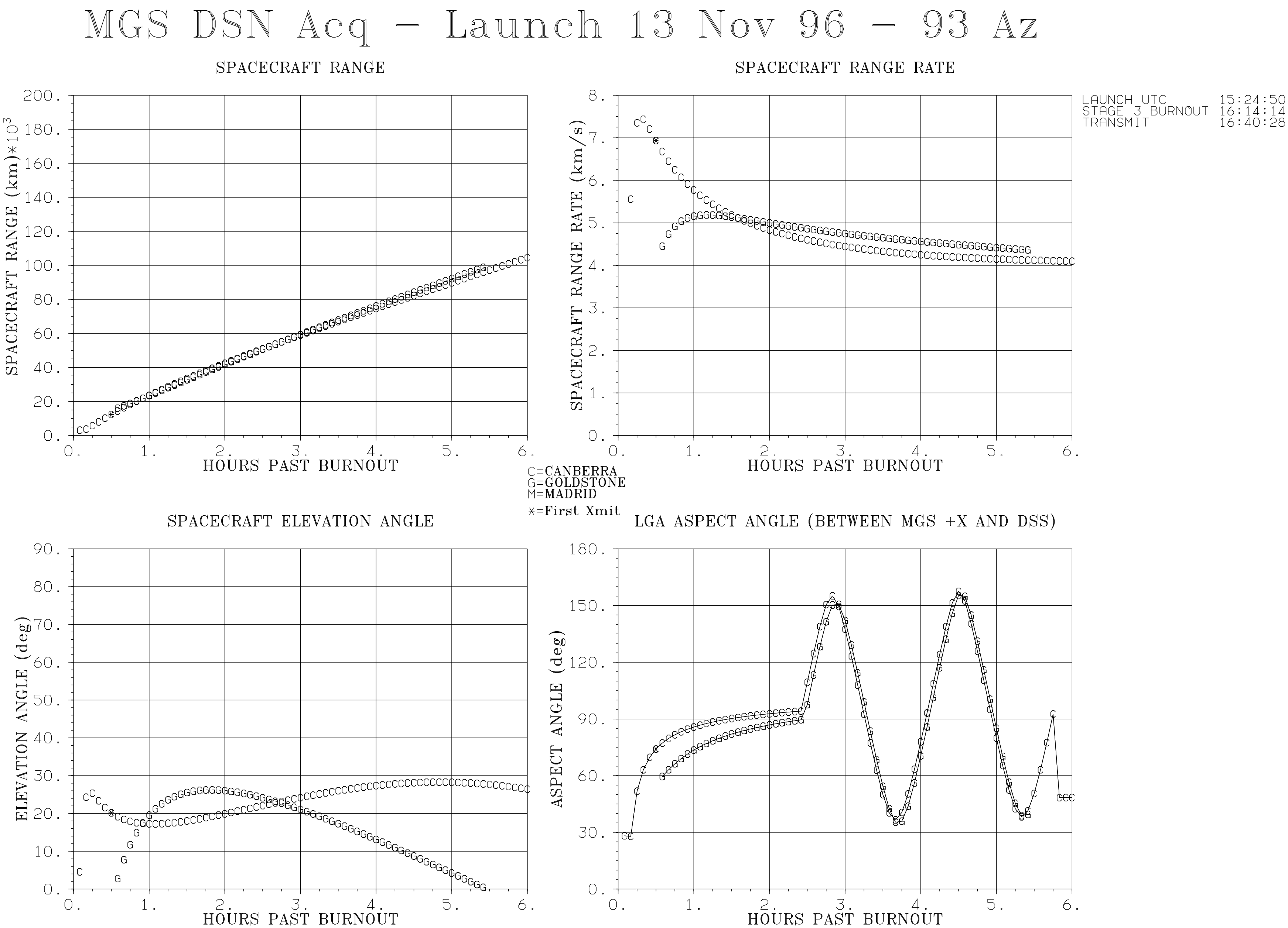

MGS DSN Acq - Launch 12 Nov 96 - 93 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 15:46:14
STAGE 3 BURNOUT 16:34:45
TRANSMIT 17:00:59
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT


MGS DSN Acq - Launch 12 Nov 96 - 93 Az
SPACECRAFT AZIMUTH RATE
AZIMUTH RATE (deg/s)
HOURS PAST BURNOUT
LAUNCH UTC 15:46:14
STAGE 3 BURNOUT 16:34:45
TRANSMIT 17:00:59
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)
line = xmit off
SPACECRAFT ELEVATION RATE
ELEVATION RATE (deg/s)
HOURS PAST BURNOUT
26 METER X-Y MOUNT ANGULAR RATES
X,Y RATE (deg/s)
HOURS PAST BURNOUT
dash = X
solid = Y


MGS DSN Acq - Launch 12 Nov 96 - 99.89 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:58:15
STAGE 3 BURNOUT 17:42:54
TRANSMIT 18:09:08
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

MGS DSN Acq - Launch 12 Nov 96 - 99.89 Az

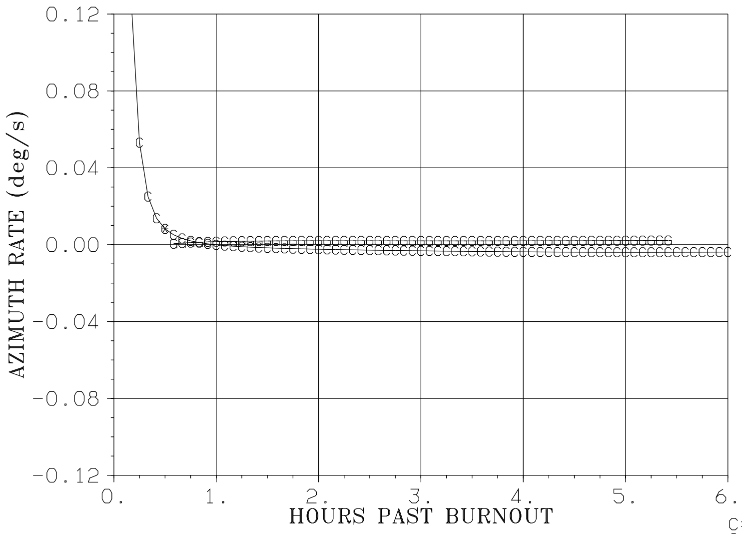


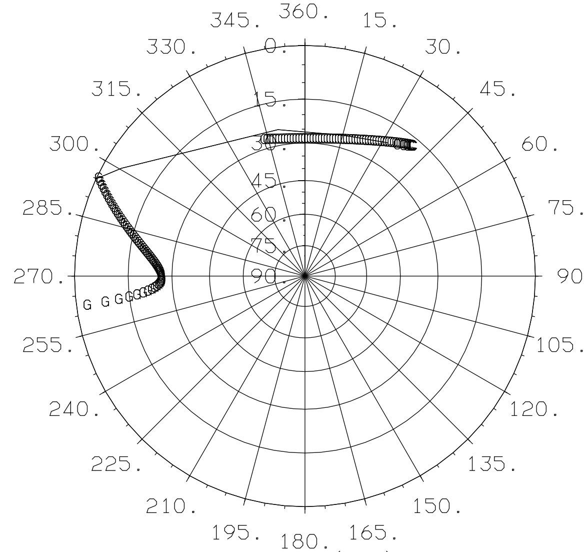

MGS DSN Acq - Launch 13 Nov 96 - 93 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 15:24:50
STAGE 3 BURNOUT 16:14:14
TRANSMIT 16:40:28
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

MGS DSN Acq - Launch 13 Nov 96 - 93 Az

LAUNCH UTC 15:24:50
STAGE 3 BURNOUT 16:14:14
TRANSMIT 16:40:28

SPACECRAFT AZIMUTH RATE



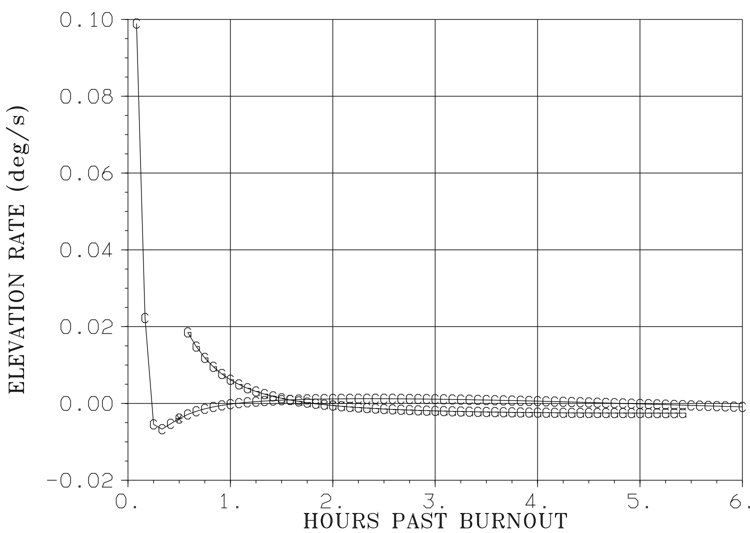


Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)

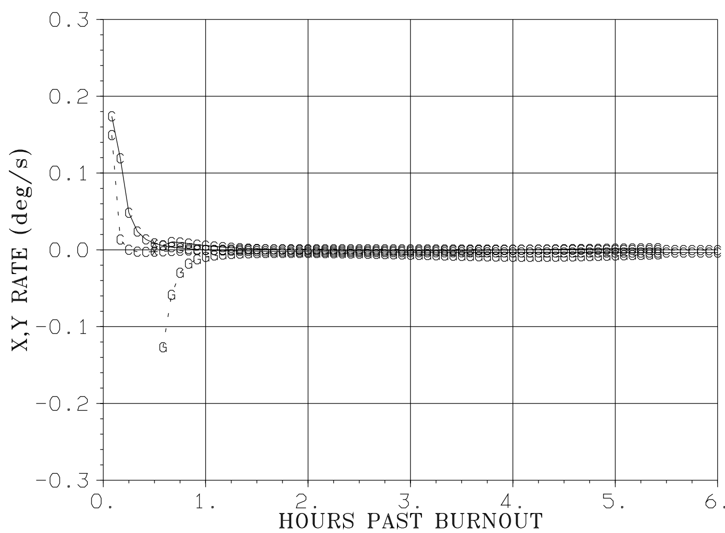
line = xmit off

C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

SPACECRAFT ELEVATION RATE

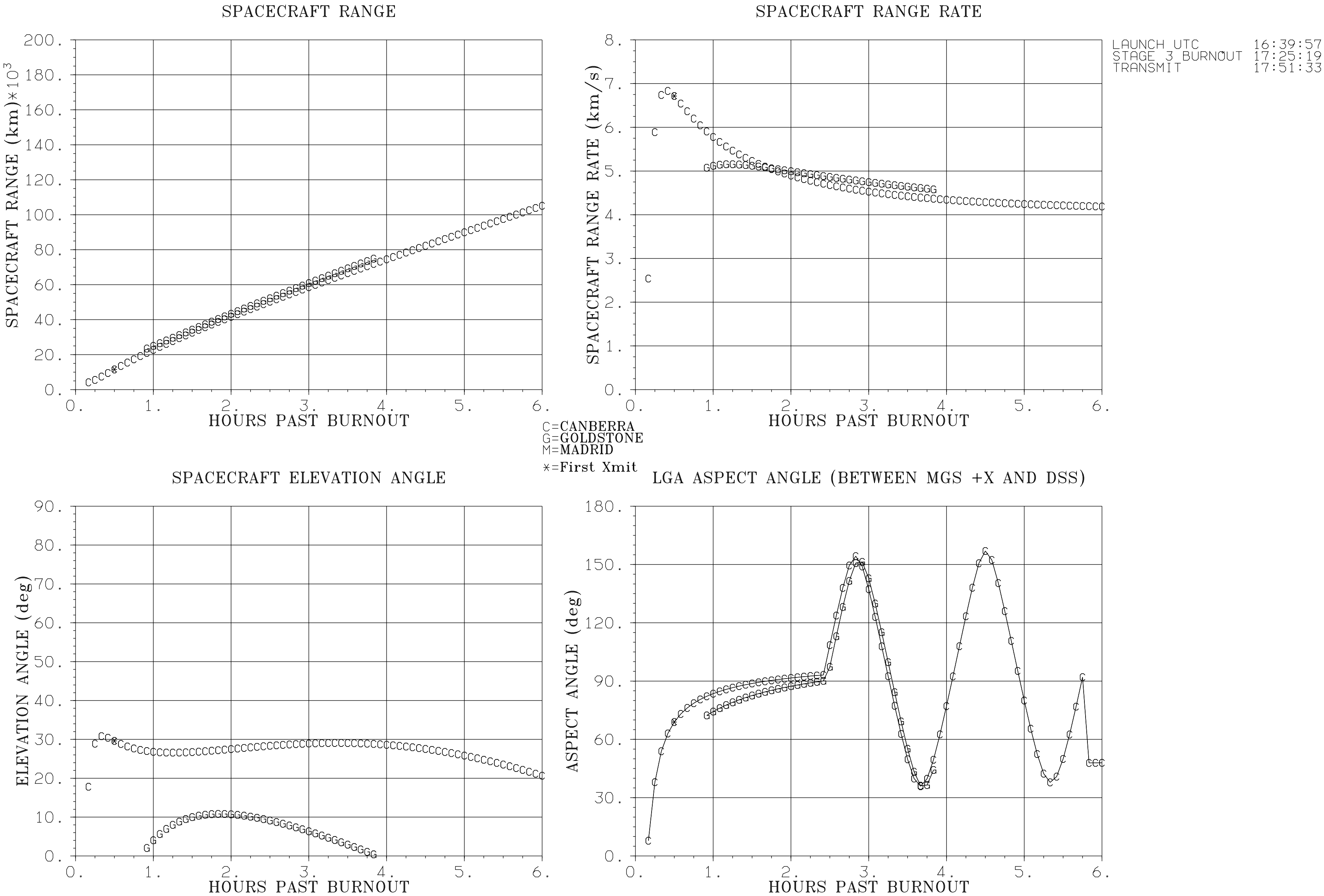


26 METER X-Y MOUNT ANGULAR RATES

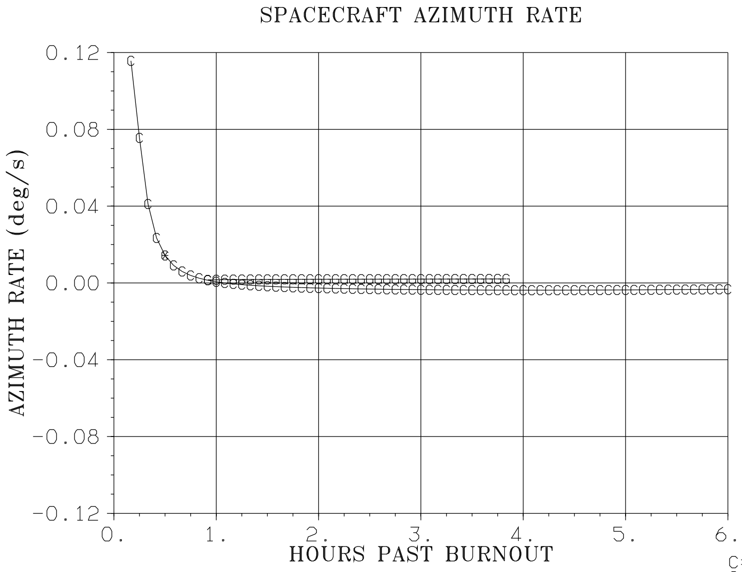


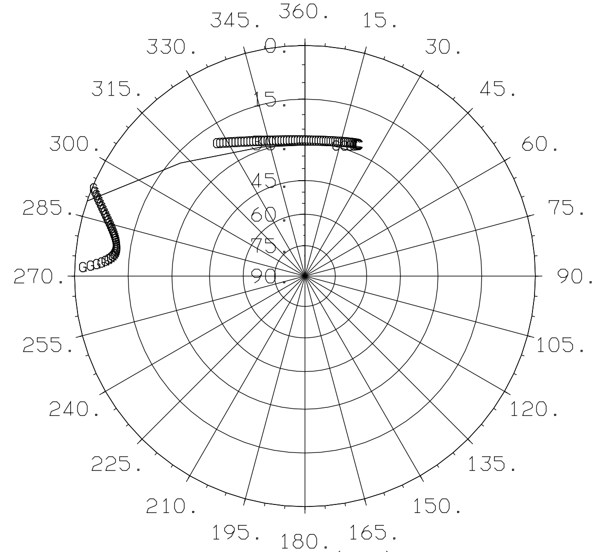
dash = X
solid = Y

MGS DSN Acq - Launch 13 Nov 96 - 99.89 Az



MGS DSN Acq - Launch 13 Nov 96 - 99.89 Az

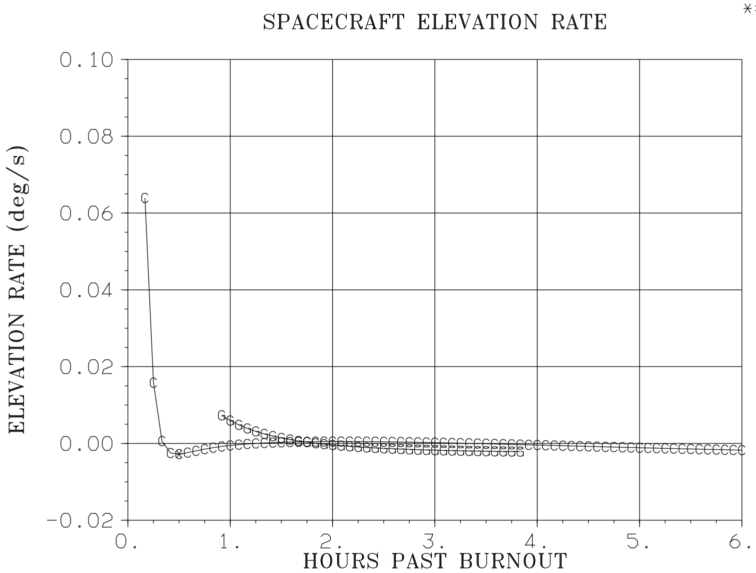


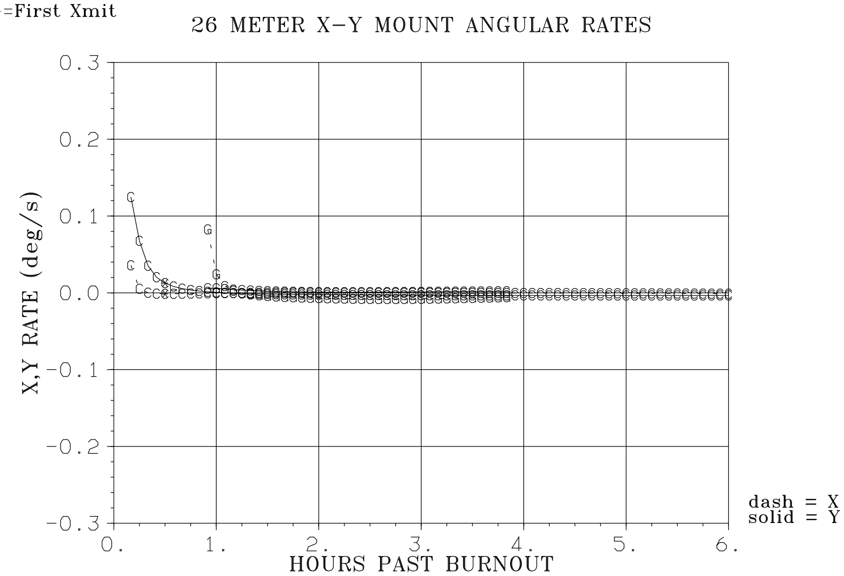


LAUNCH UTC 16:39:57
STAGE 3 BURNOUT 17:25:19
TRANSMIT 17:51:33

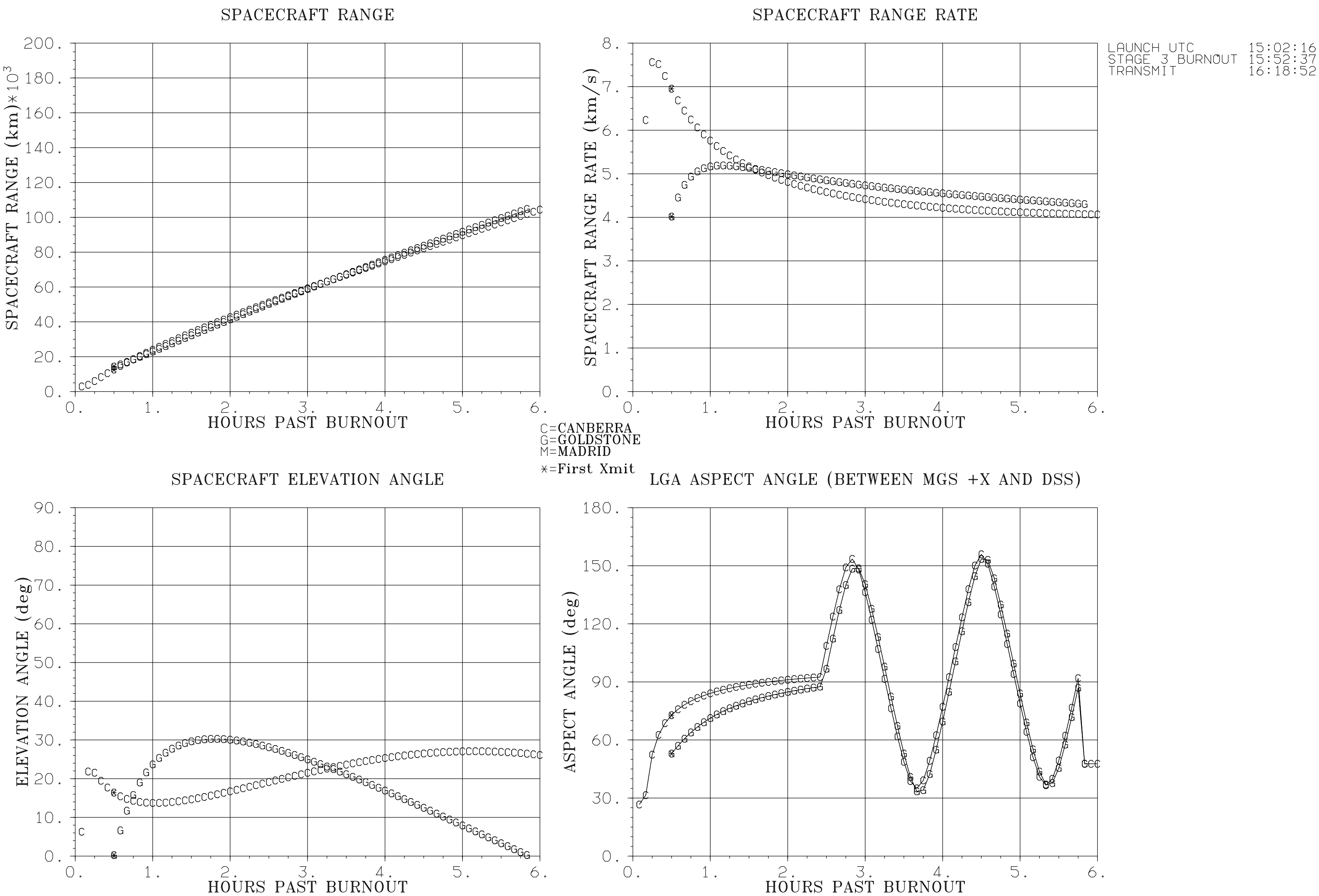
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

line = xmit off



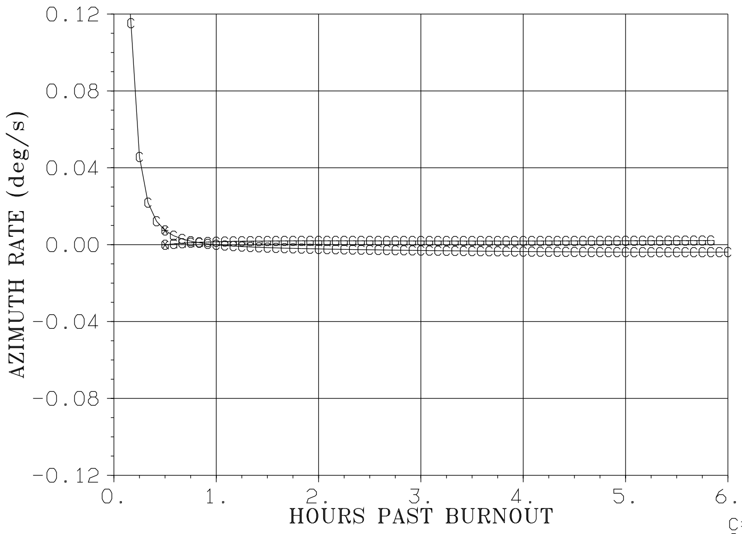


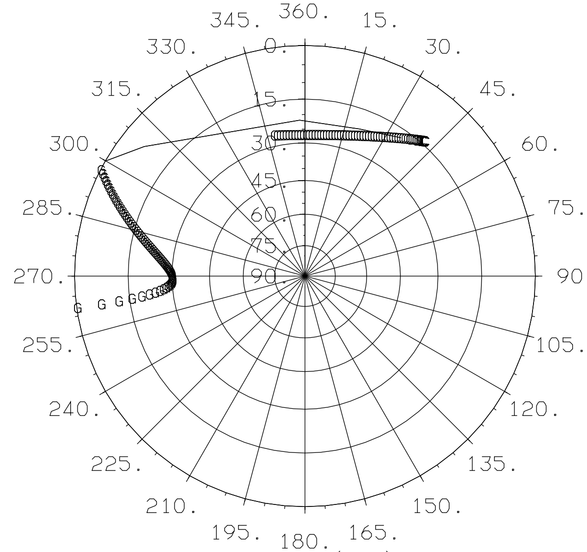
MGS DSN Acq - Launch 14 Nov 96 - 93 Az



MGS DSN Acq – Launch 14 Nov 96 – 93 Az

SPACECRAFT AZIMUTH RATE





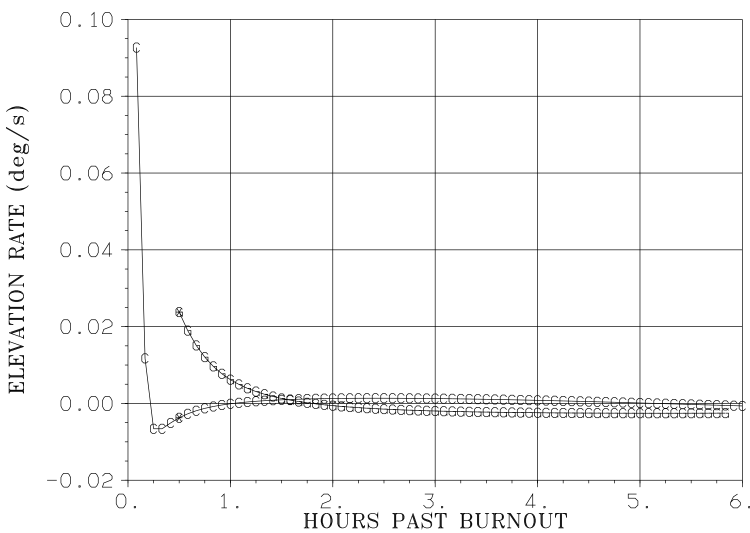
LAUNCH UTC 15:02:16
STAGE 3 BURNOUT 15:52:37
TRANSMIT 16:18:52

C=CANBERRA
G=GOLDSTONE
M=MADRID
∗=First Xmit

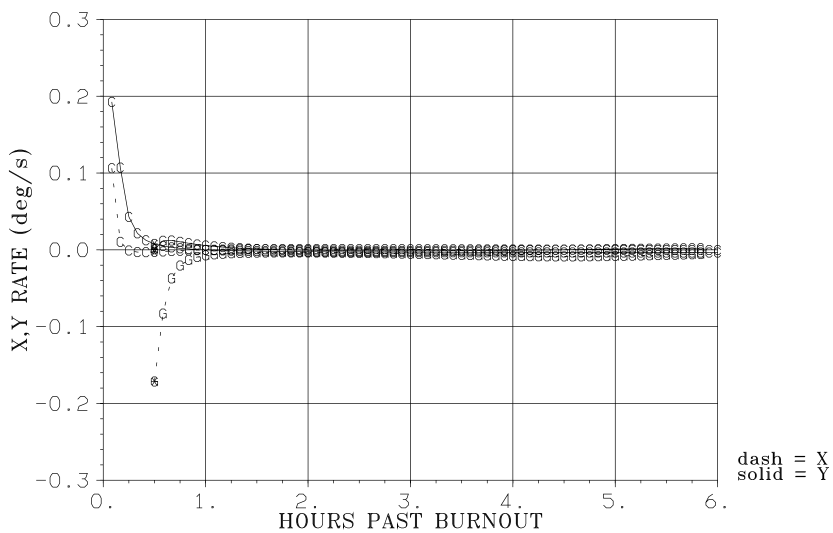
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)

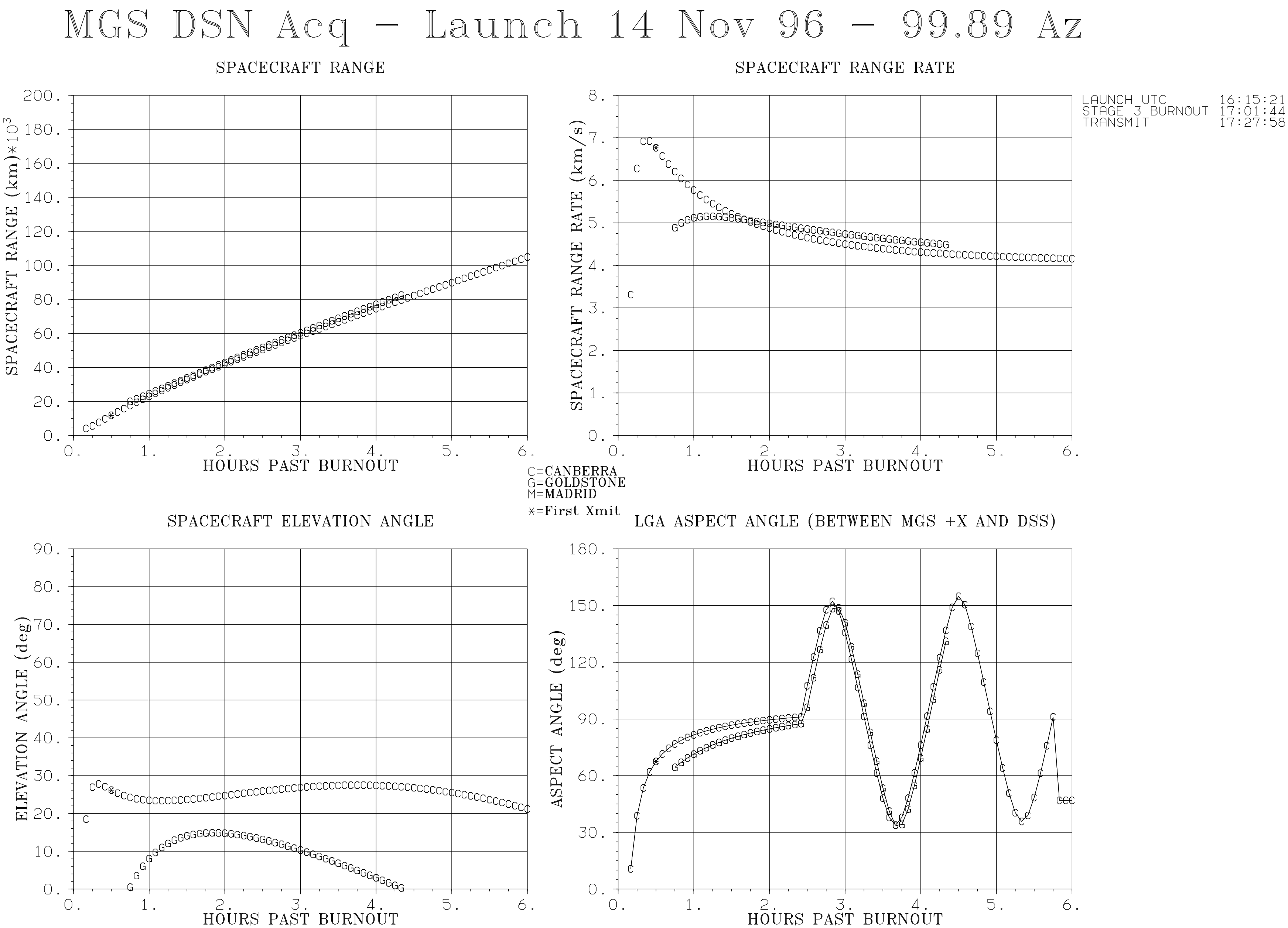
line = xmit off

SPACECRAFT ELEVATION RATE



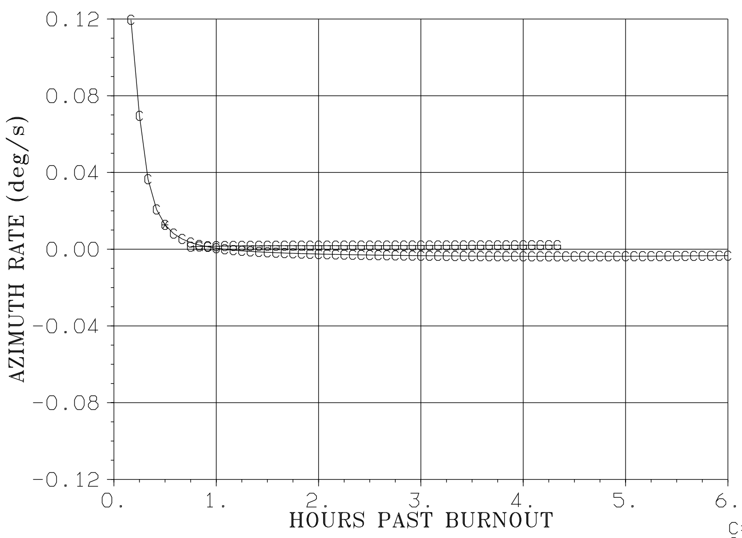
26 METER X–Y MOUNT ANGULAR RATES

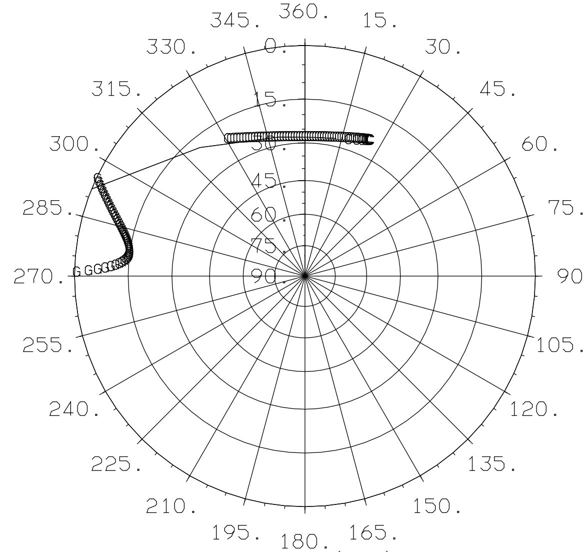



MGS DSN Acq - Launch 14 Nov 96 - 99.89 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:15:21
STAGE 3 BURNOUT 17:01:44
TRANSMIT 17:27:58
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

MGS DSN Acq - Launch 14 Nov 96 - 99.89 Az

SPACECRAFT AZIMUTH RATE





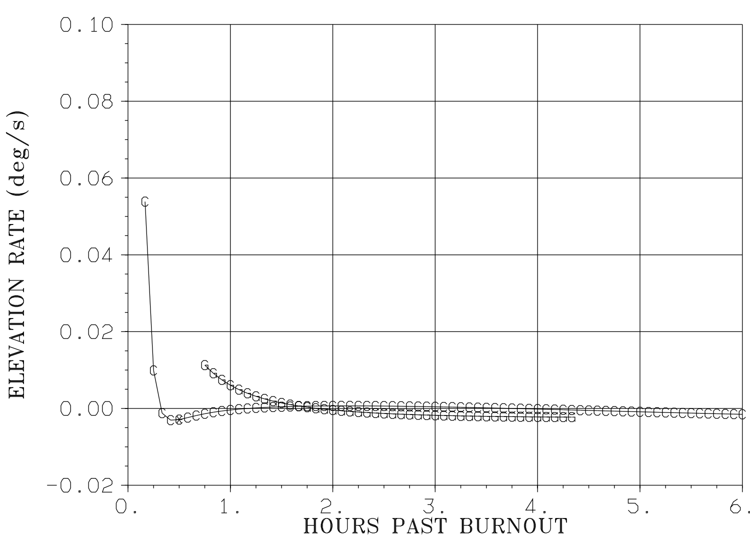
LAUNCH UTC 16:15:21
STAGE 3 BURNOUT 17:01:44
TRANSMIT 17:27:58

C=CANBERRA
G=GOLDSTONE
M=MADRID
∗=First Xmit

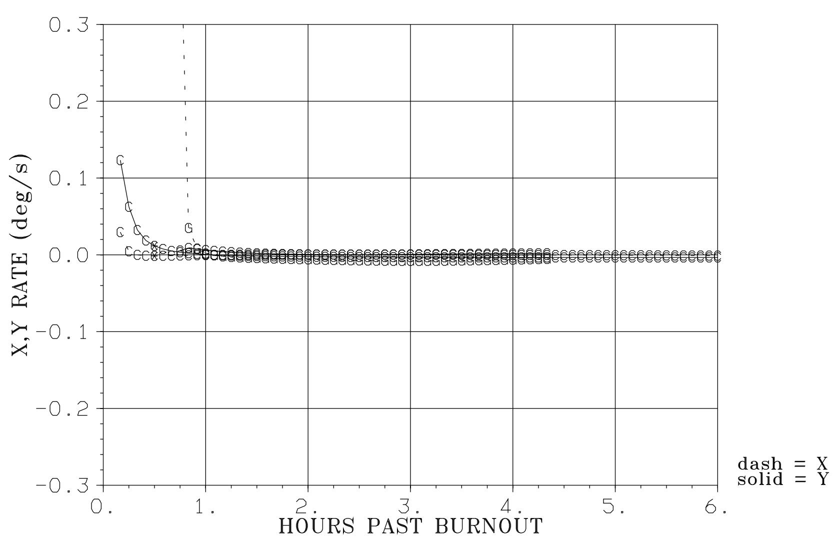
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)

line = xmit off

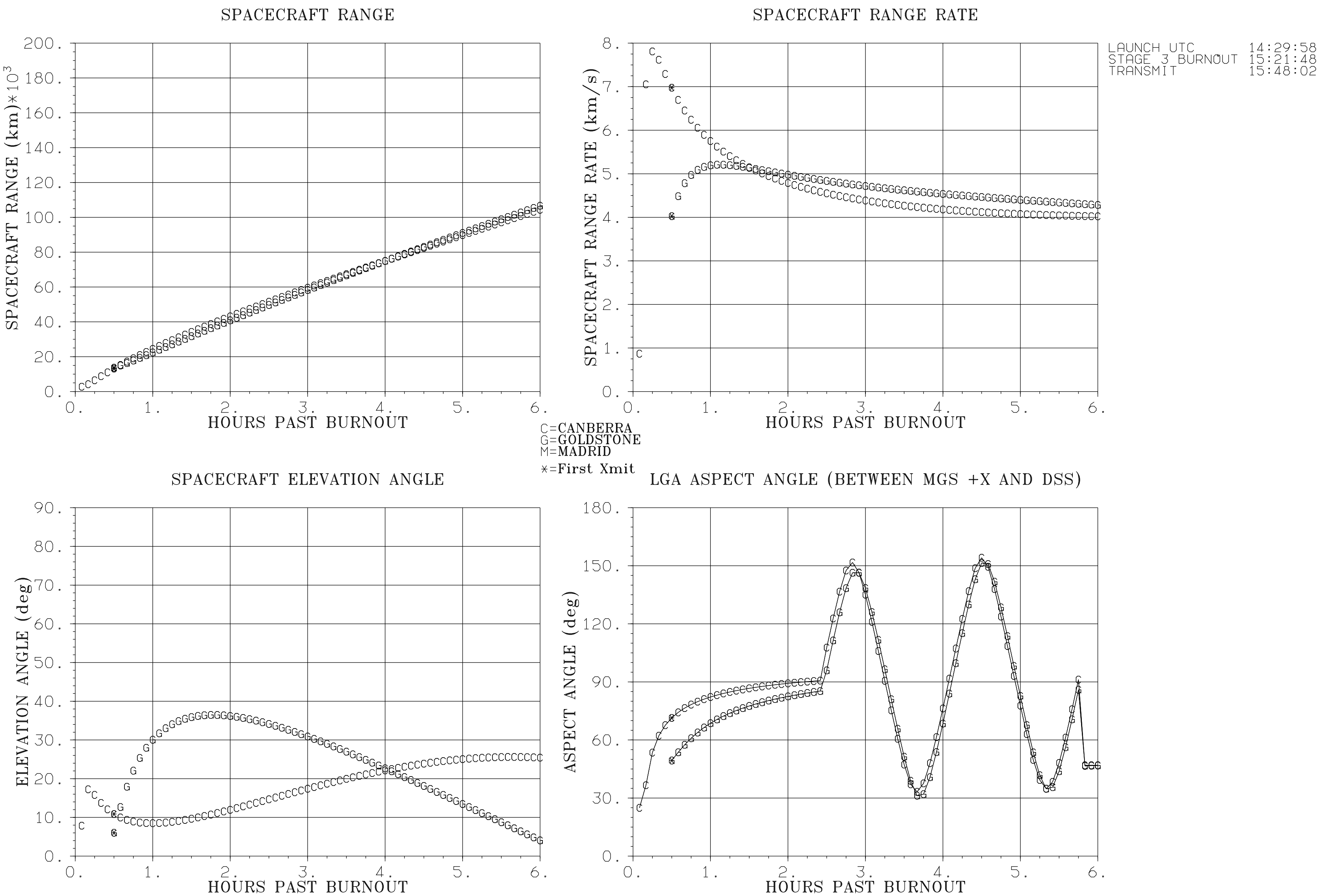
SPACECRAFT ELEVATION RATE

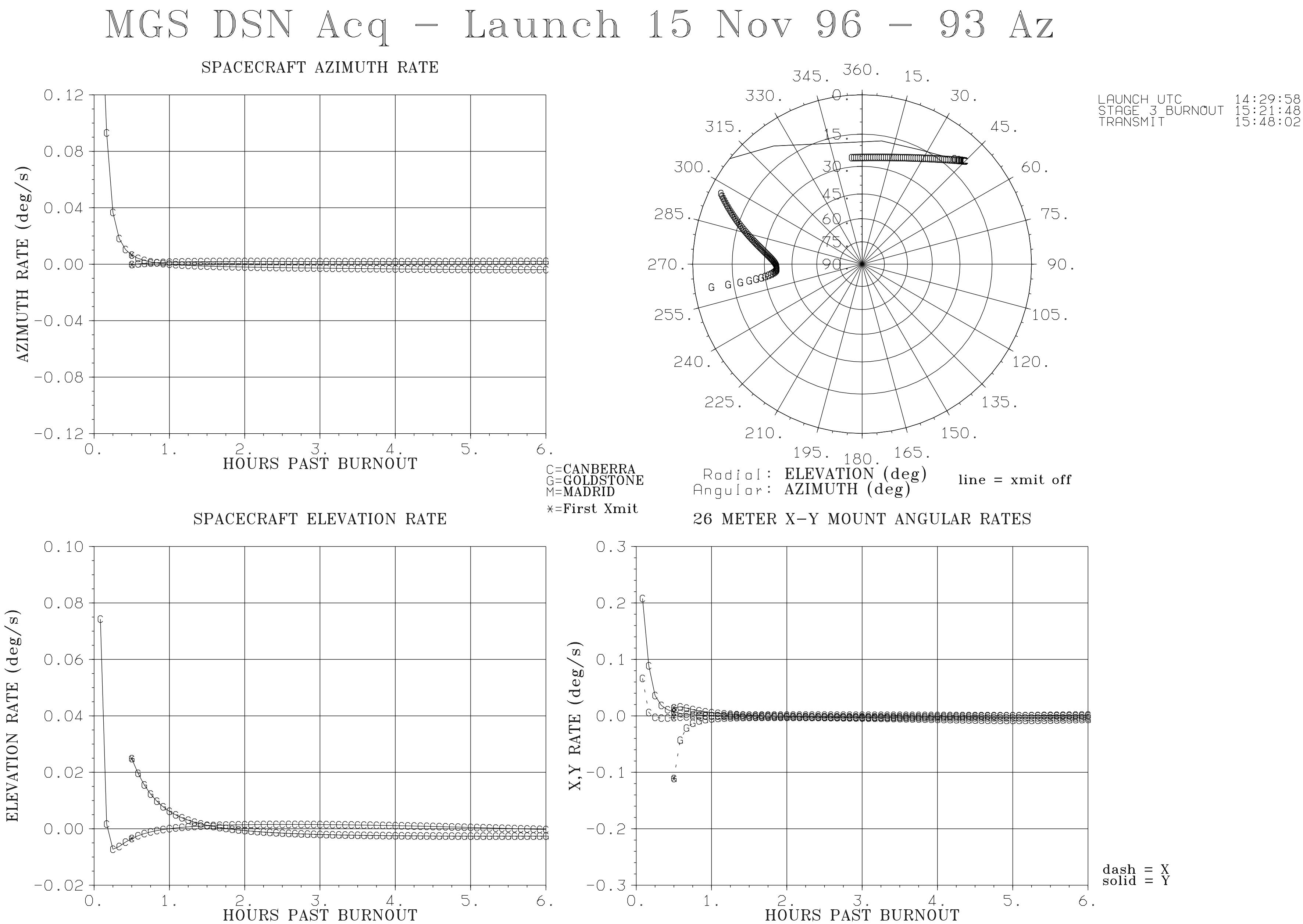


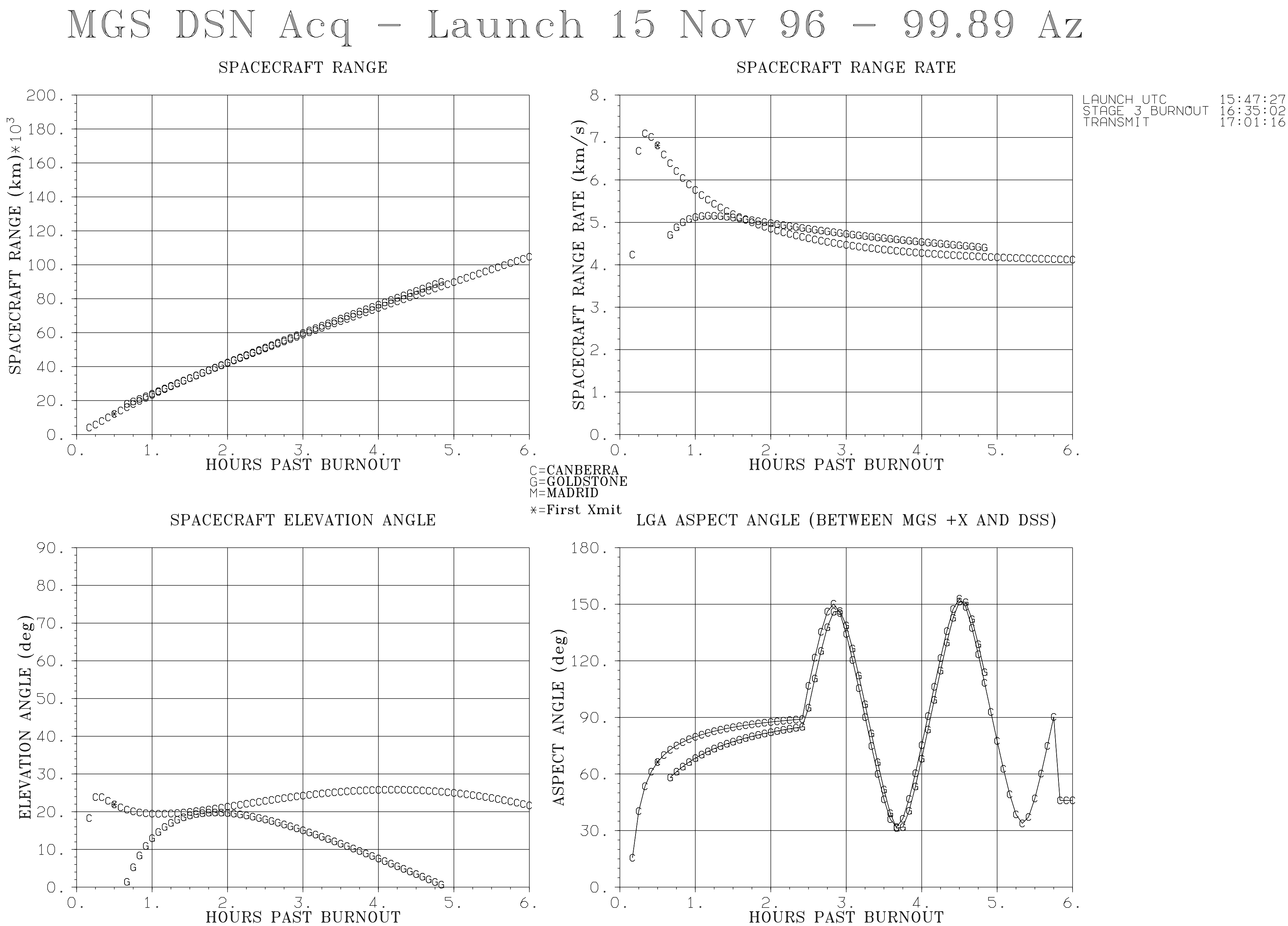
26 METER X-Y MOUNT ANGULAR RATES



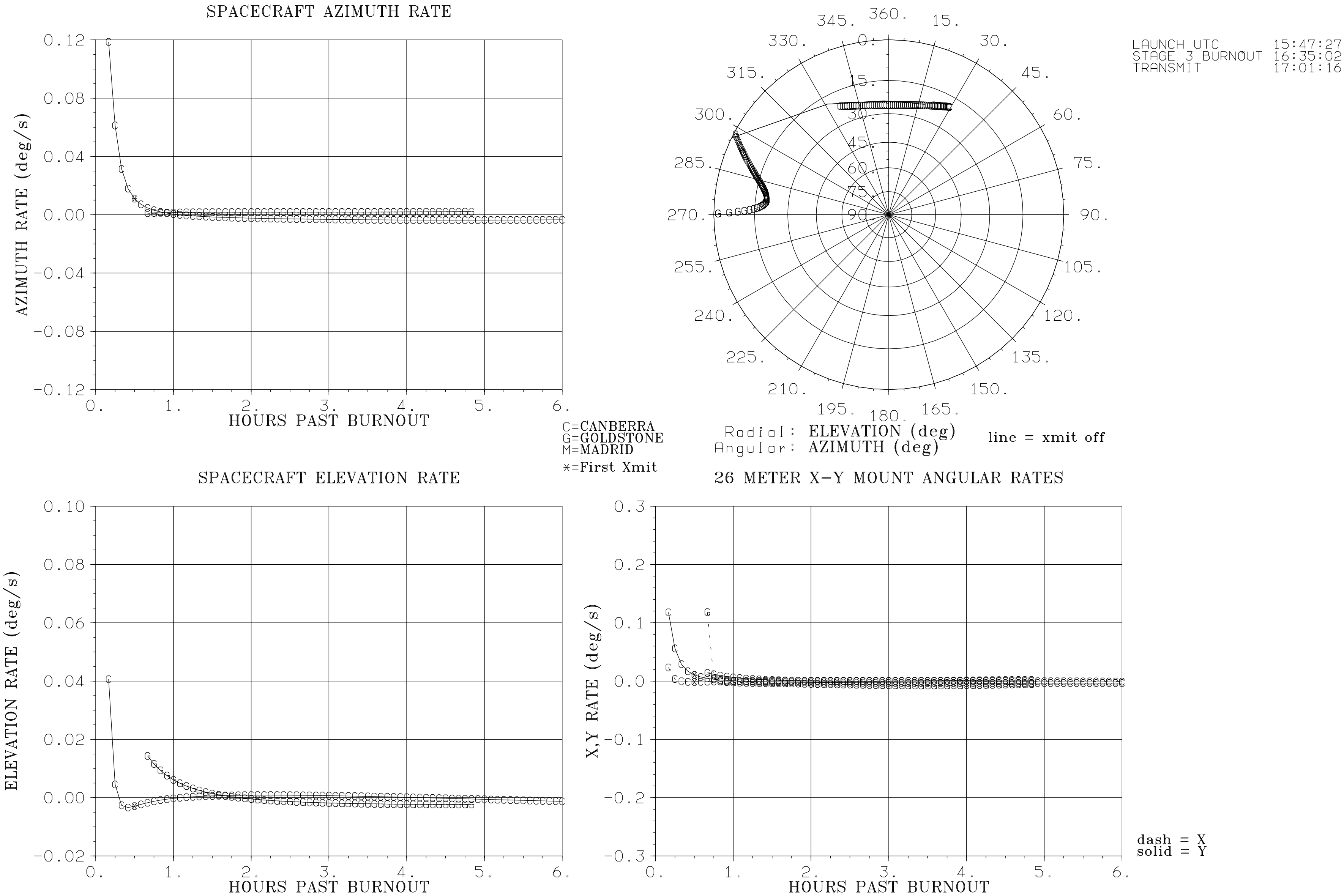
MGS DSN Acq – Launch 15 Nov 96 – 93 Az

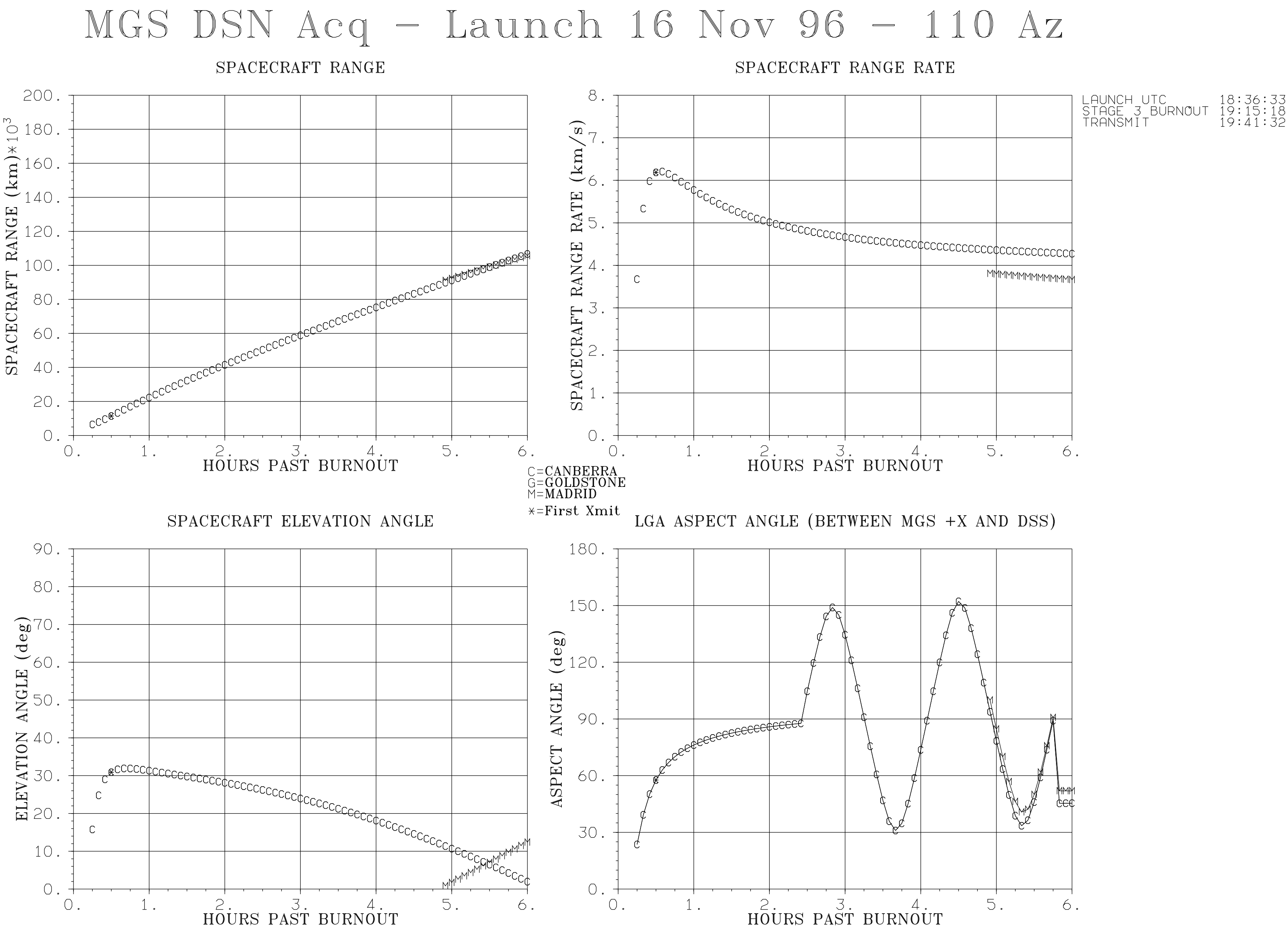



MGS DSN Acq - Launch 15 Nov 96 - 93 Az
SPACECRAFT AZIMUTH RATE
AZIMUTH RATE (deg/s)
HOURS PAST BURNOUT
LAUNCH UTC 14:29:58
STAGE 3 BURNOUT 15:21:48
TRANSMIT 15:48:02
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)
line = xmit off
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION RATE
ELEVATION RATE (deg/s)
HOURS PAST BURNOUT
26 METER X-Y MOUNT ANGULAR RATES
X,Y RATE (deg/s)
HOURS PAST BURNOUT
dash = X
solid = Y

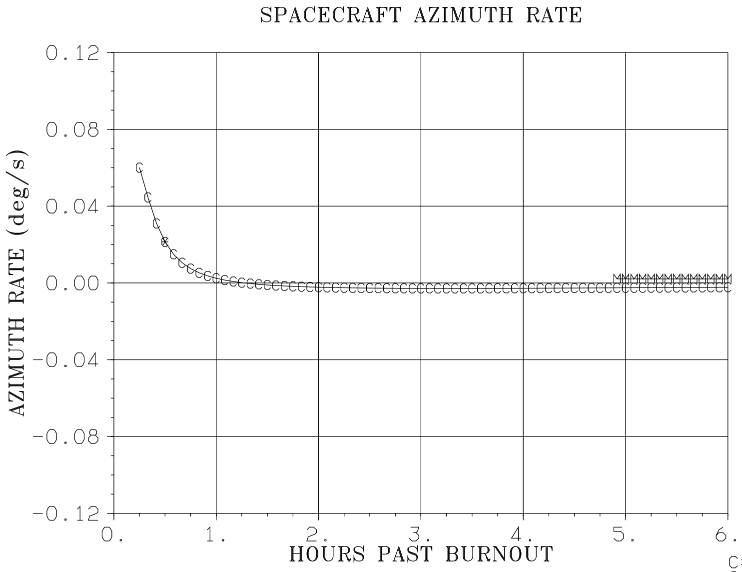

MGS DSN Acq - Launch 15 Nov 96 - 99.89 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 15:47:27
STAGE 3 BURNOUT 16:35:02
TRANSMIT 17:01:16
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

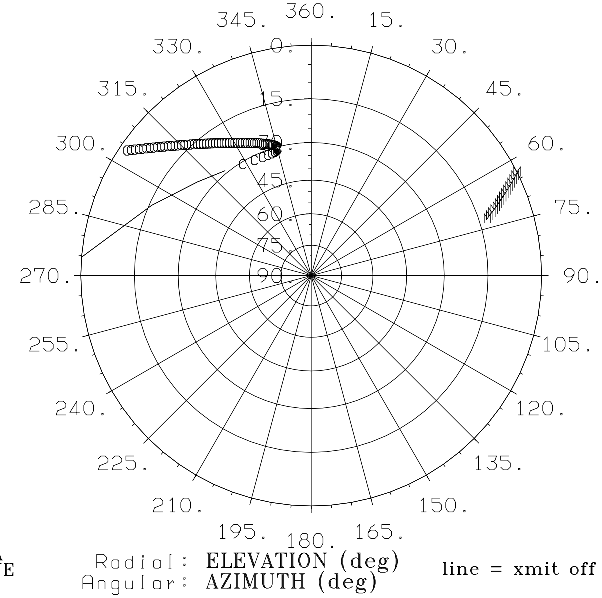
MGS DSN Acq – Launch 15 Nov 96 – 99.89 Az




MGS DSN Acq - Launch 16 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 18:36:33
STAGE 3 BURNOUT 19:15:18
TRANSMIT 19:41:32
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

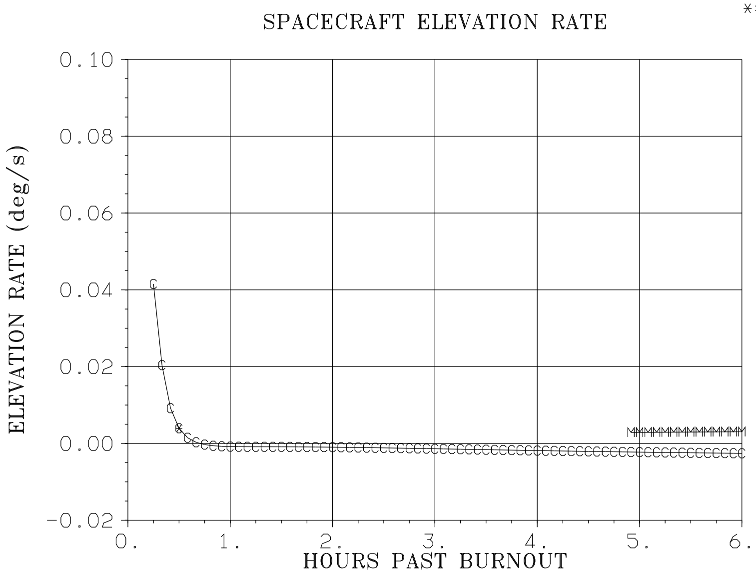
MGS DSN Acq - Launch 16 Nov 96 - 110 Az

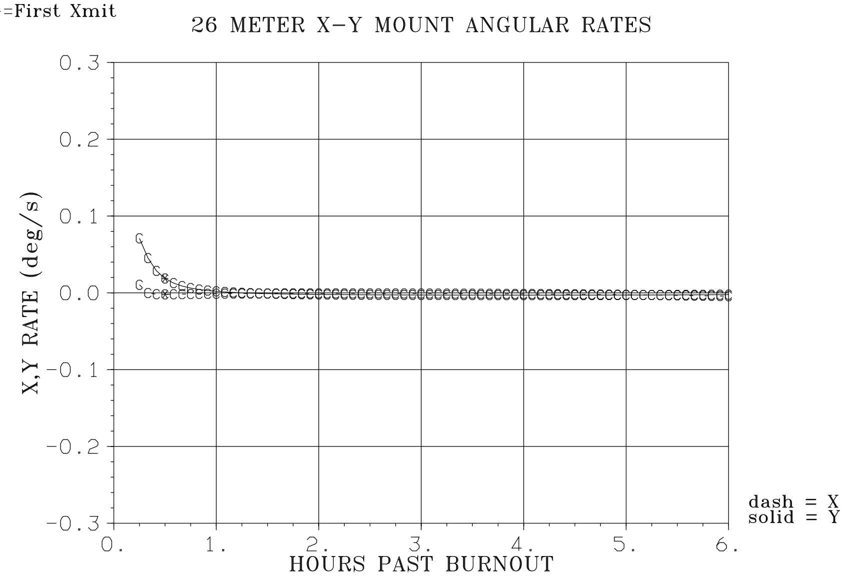


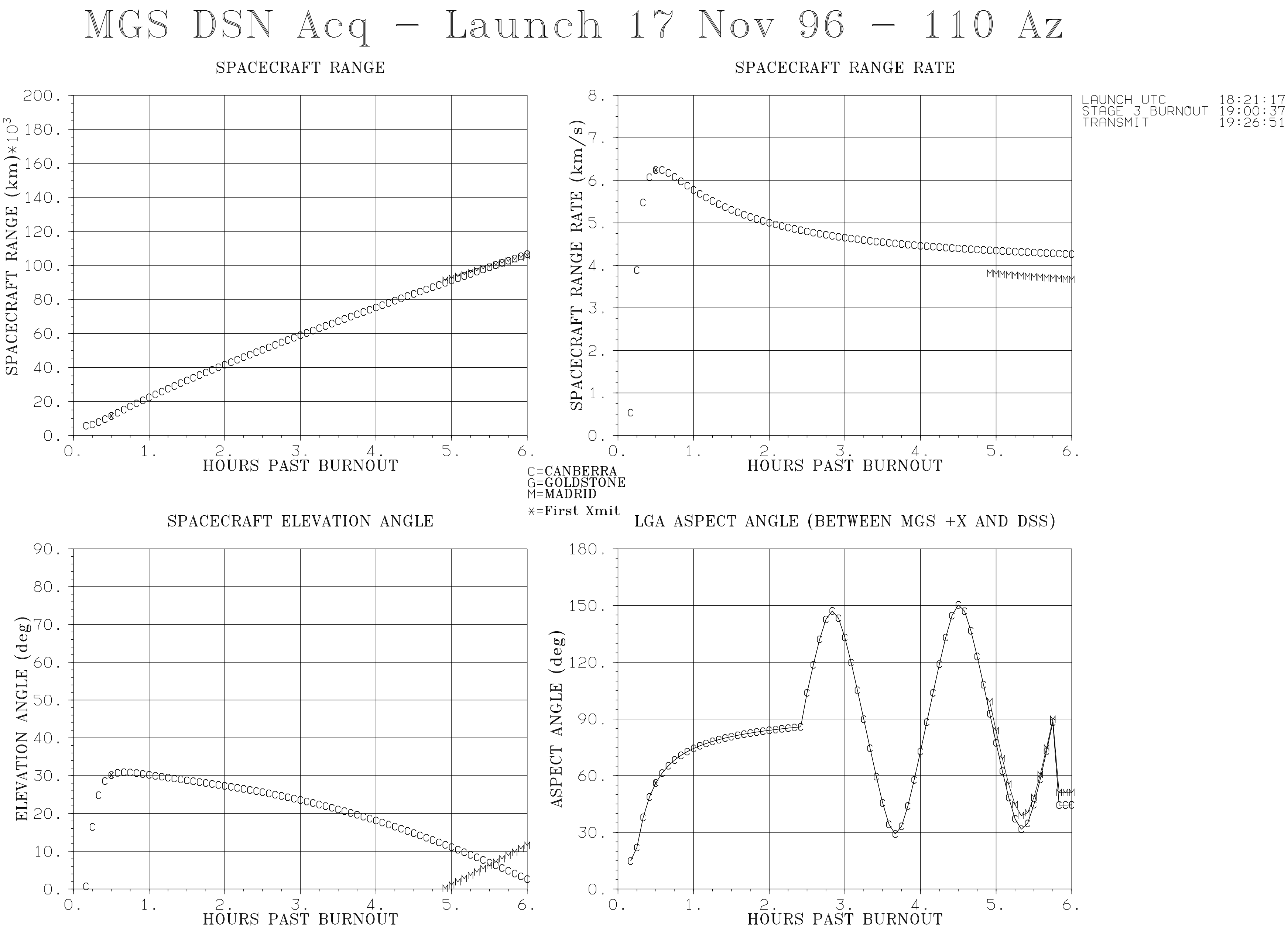


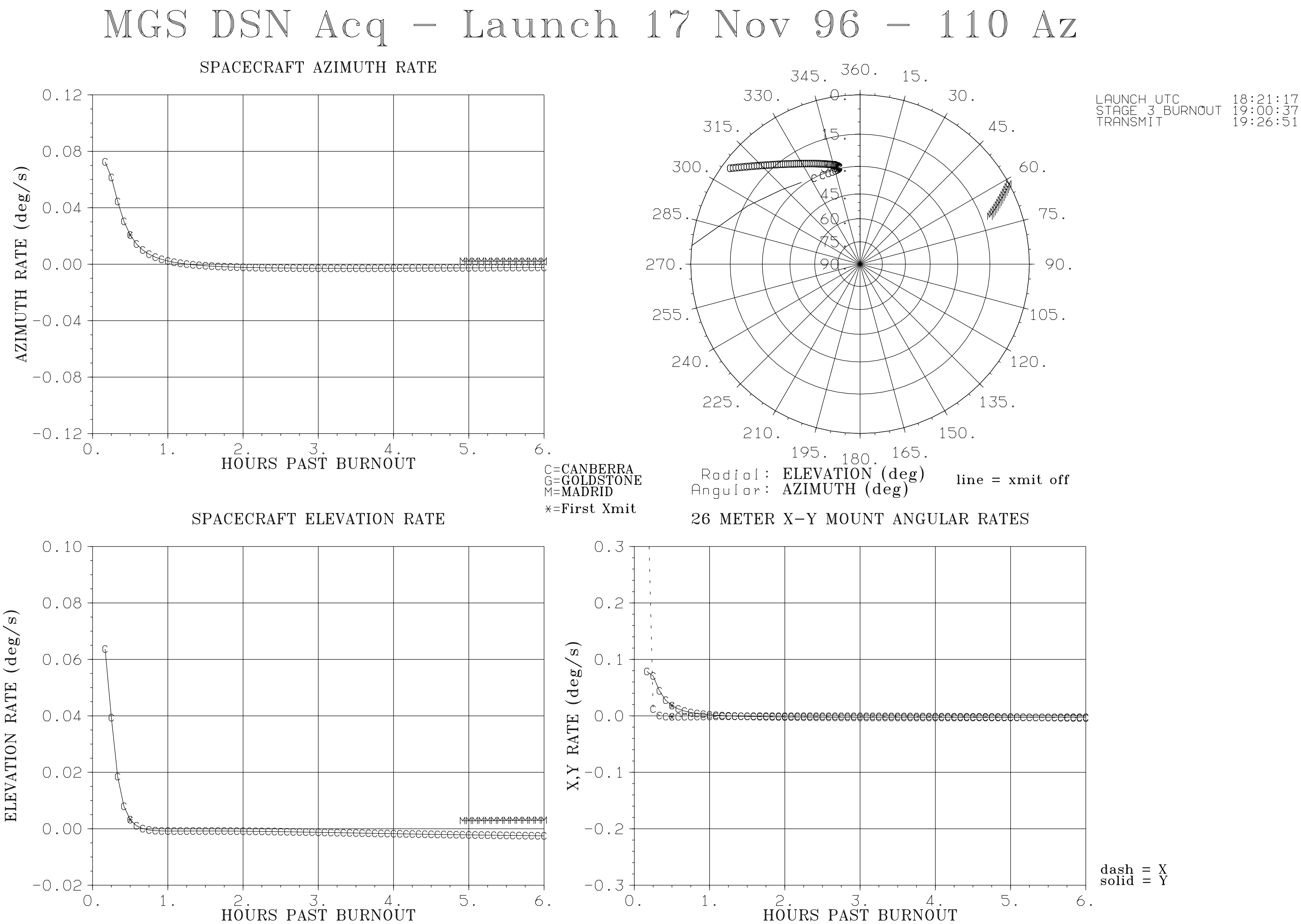
LAUNCH UTC 18:36:33
STAGE 3 BURNOUT 19:15:18
TRANSMIT 19:41:32

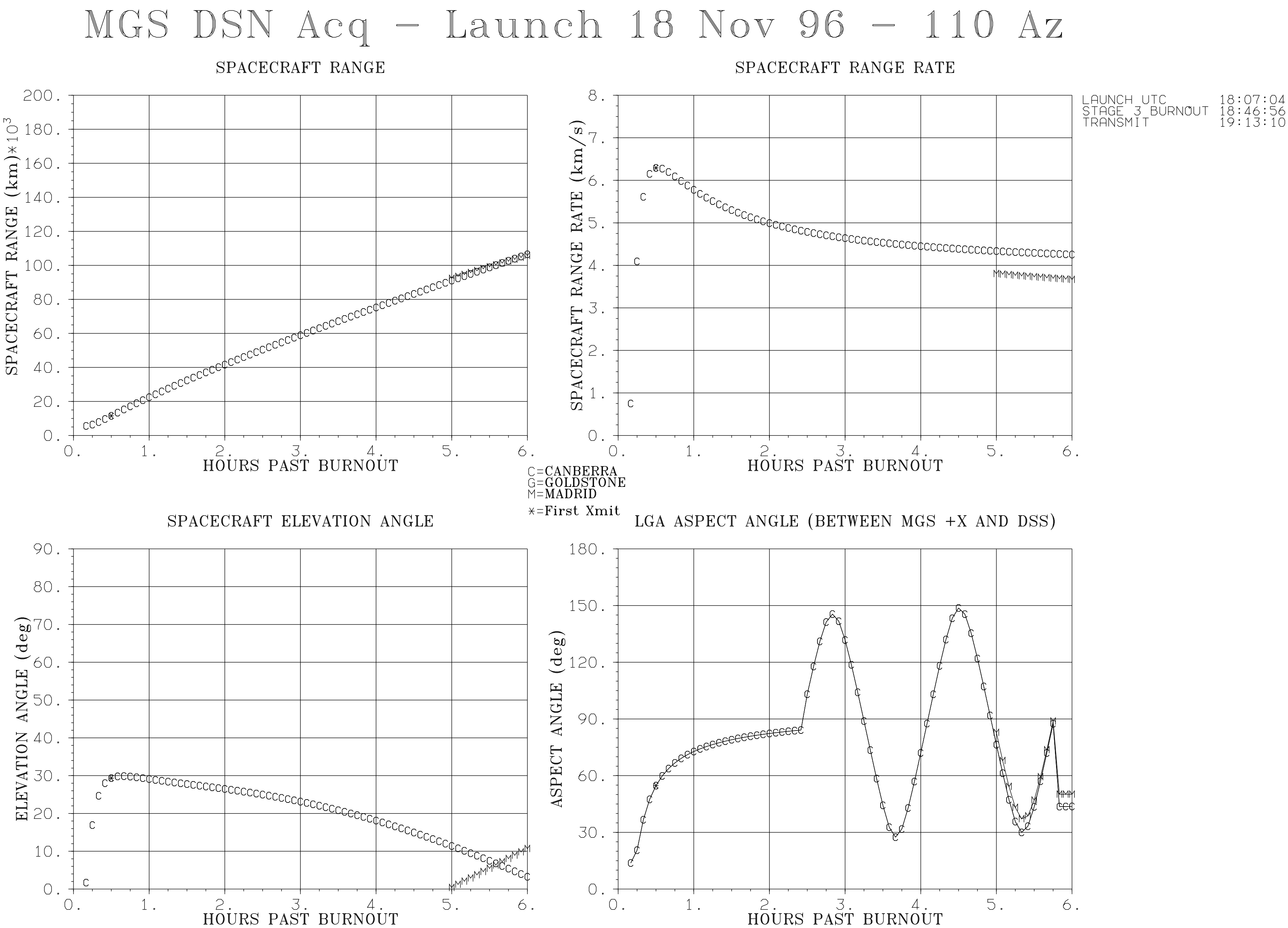
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit



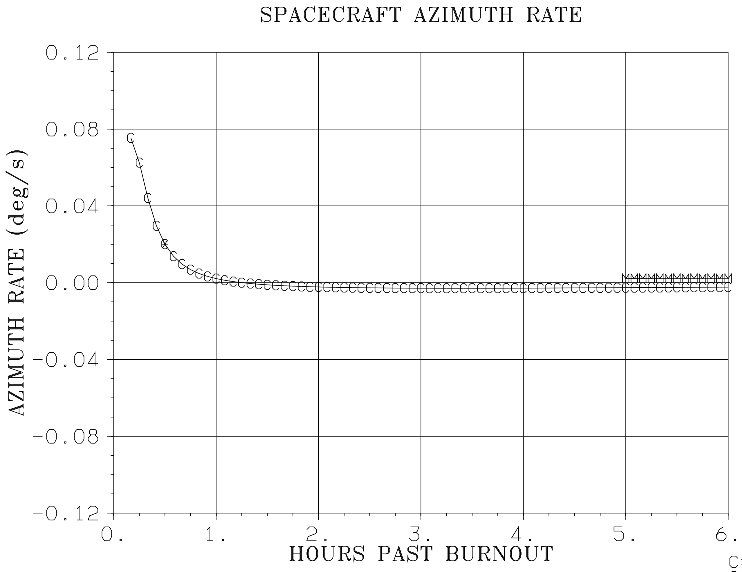


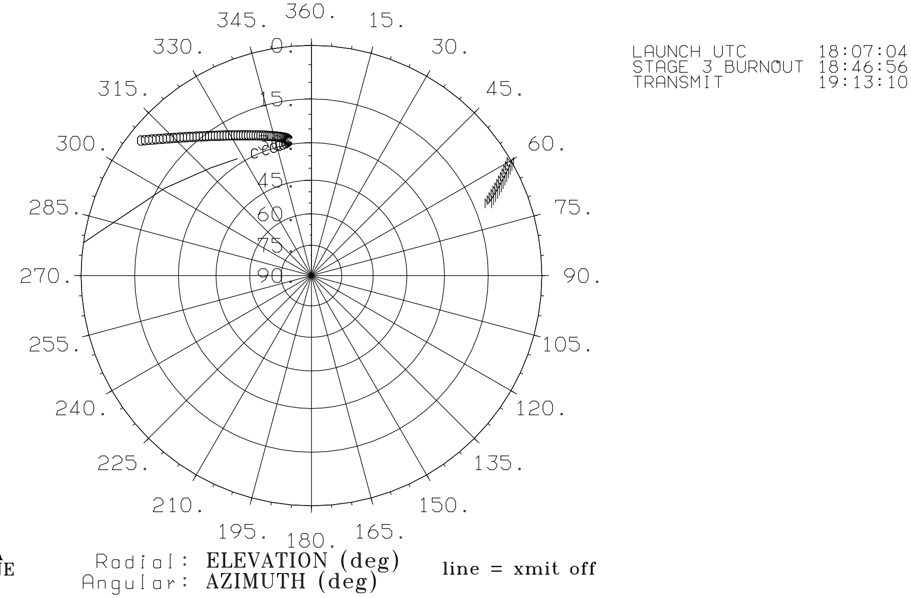

MGS DSN Acq - Launch 17 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 18:21:17
STAGE 3 BURNOUT 19:00:37
TRANSMIT 19:26:51
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT


MGS DSN Acq - Launch 17 Nov 96 - 110 Az
SPACECRAFT AZIMUTH RATE
AZIMUTH RATE (deg/s)
HOURS PAST BURNOUT
LAUNCH UTC 18:21:17
STAGE 3 BURNOUT 19:00:37
TRANSMIT 19:26:51
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)
line = xmit off
SPACECRAFT ELEVATION RATE
ELEVATION RATE (deg/s)
HOURS PAST BURNOUT
26 METER X-Y MOUNT ANGULAR RATES
X,Y RATE (deg/s)
HOURS PAST BURNOUT
dash = X
solid = Y


MGS DSN Acq - Launch 18 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 18:07:04
STAGE 3 BURNOUT 18:46:56
TRANSMIT 19:13:10
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

MGS DSN Acq - Launch 18 Nov 96 - 110 Az





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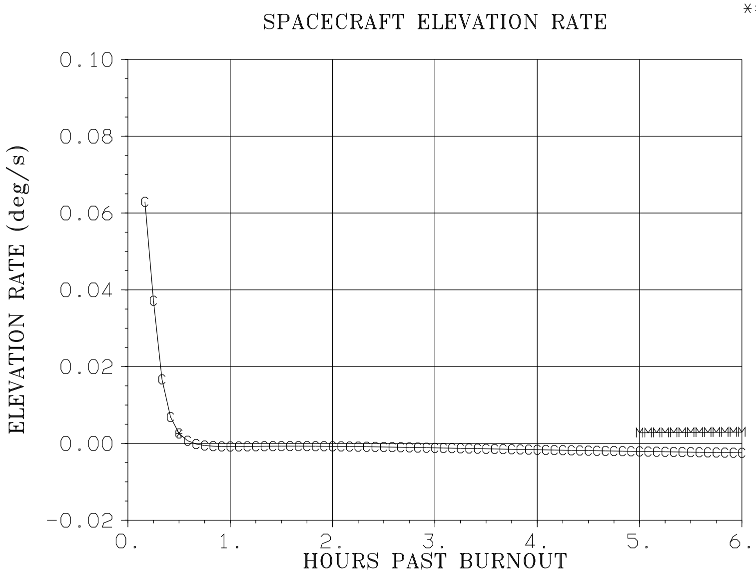
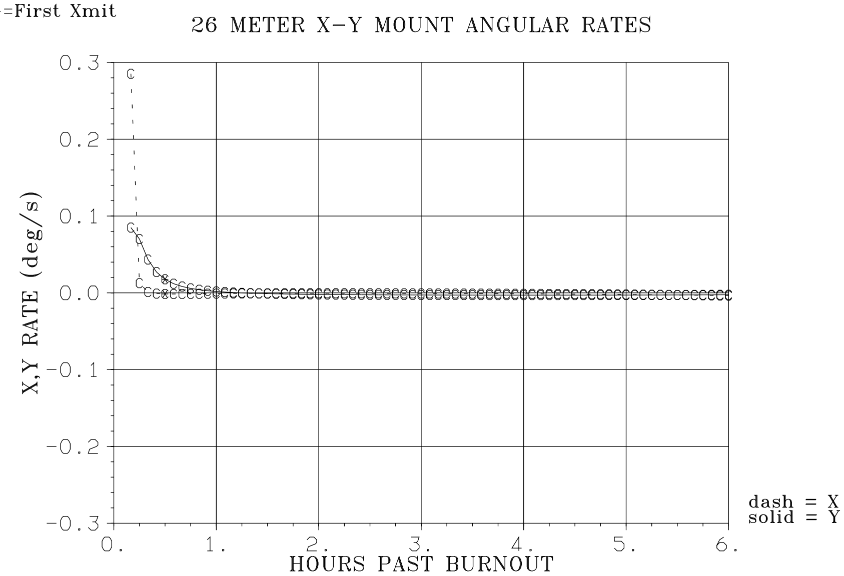
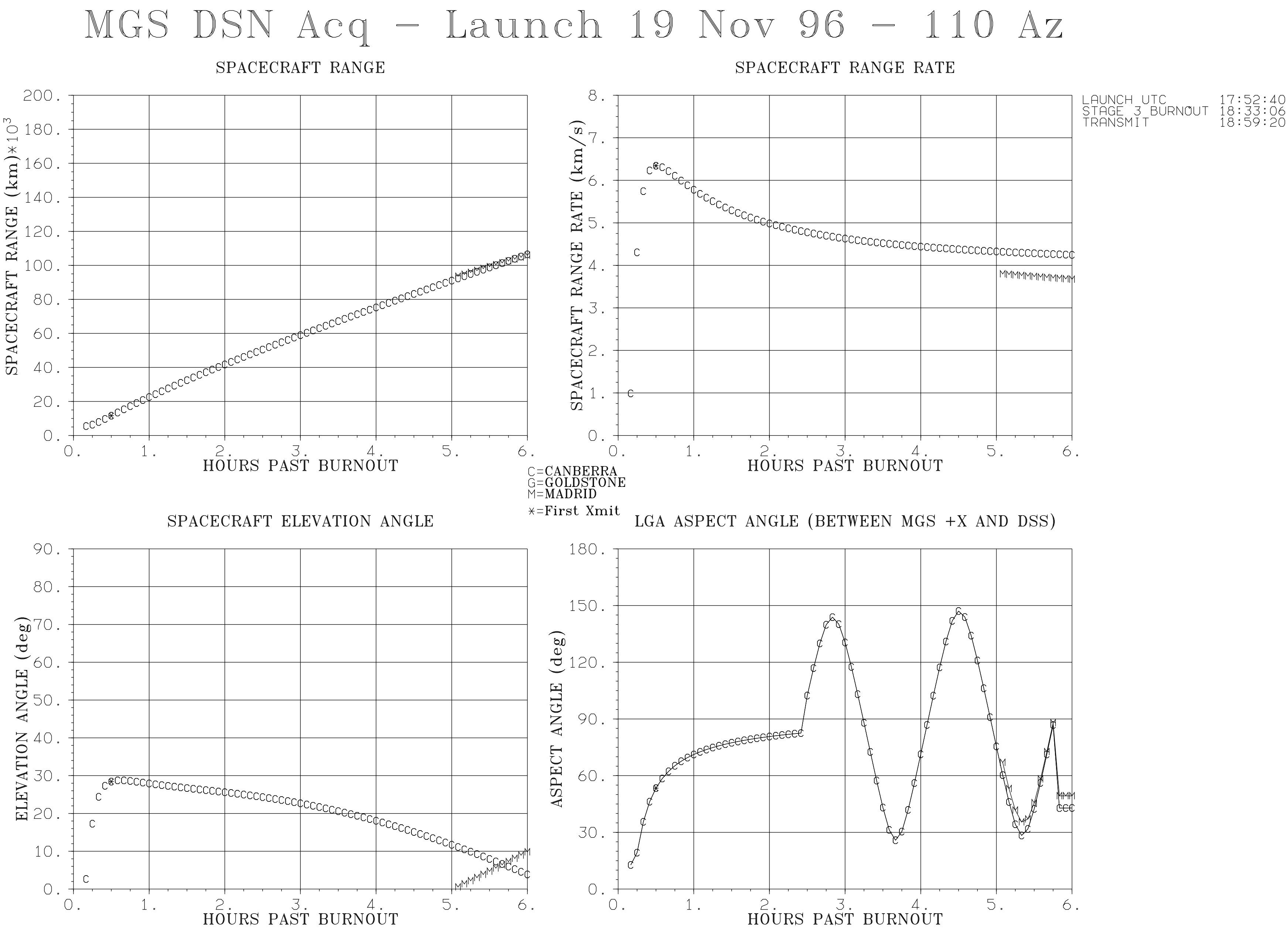
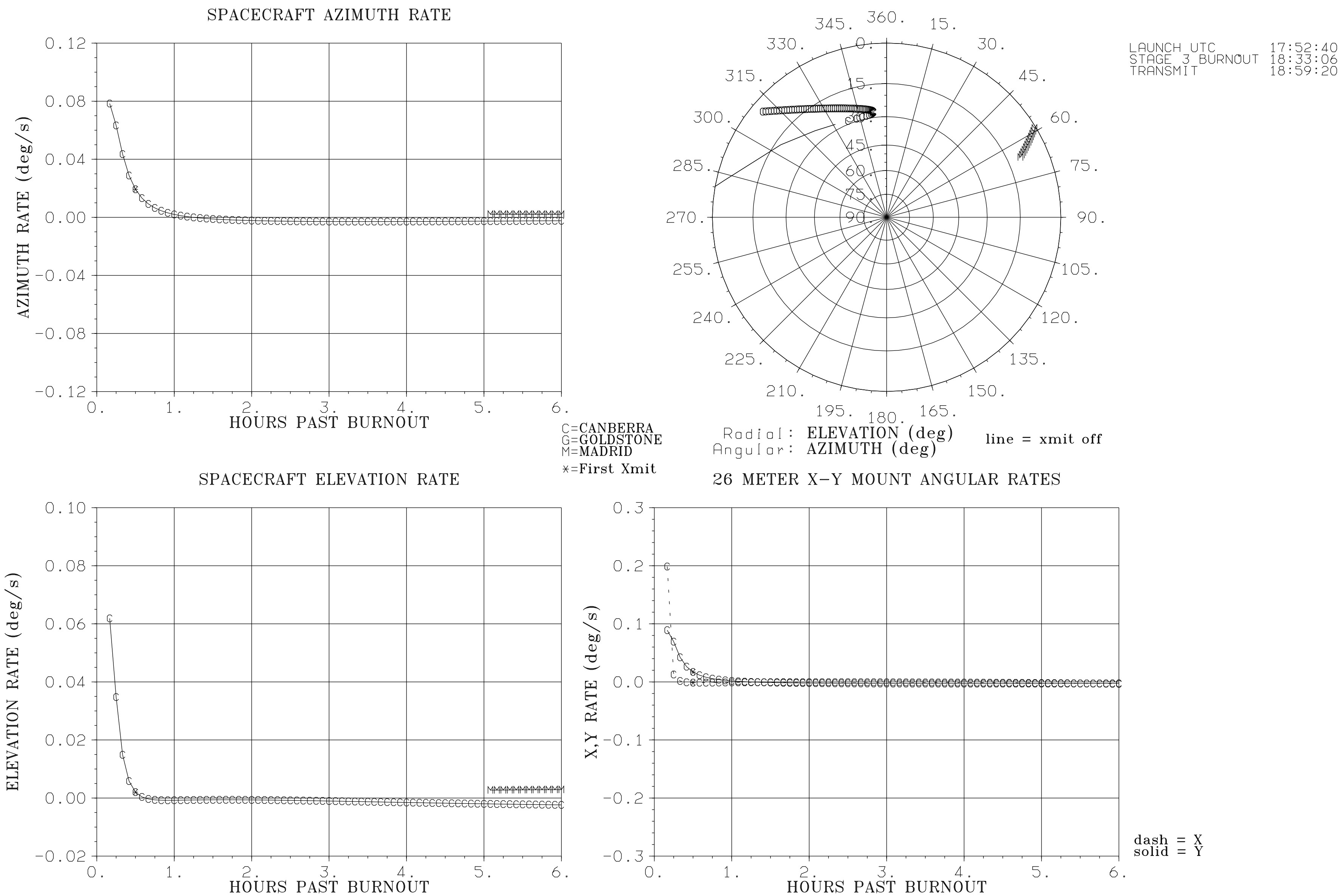
G=GOLDSTONE
M=MADRID
*=First Xmit

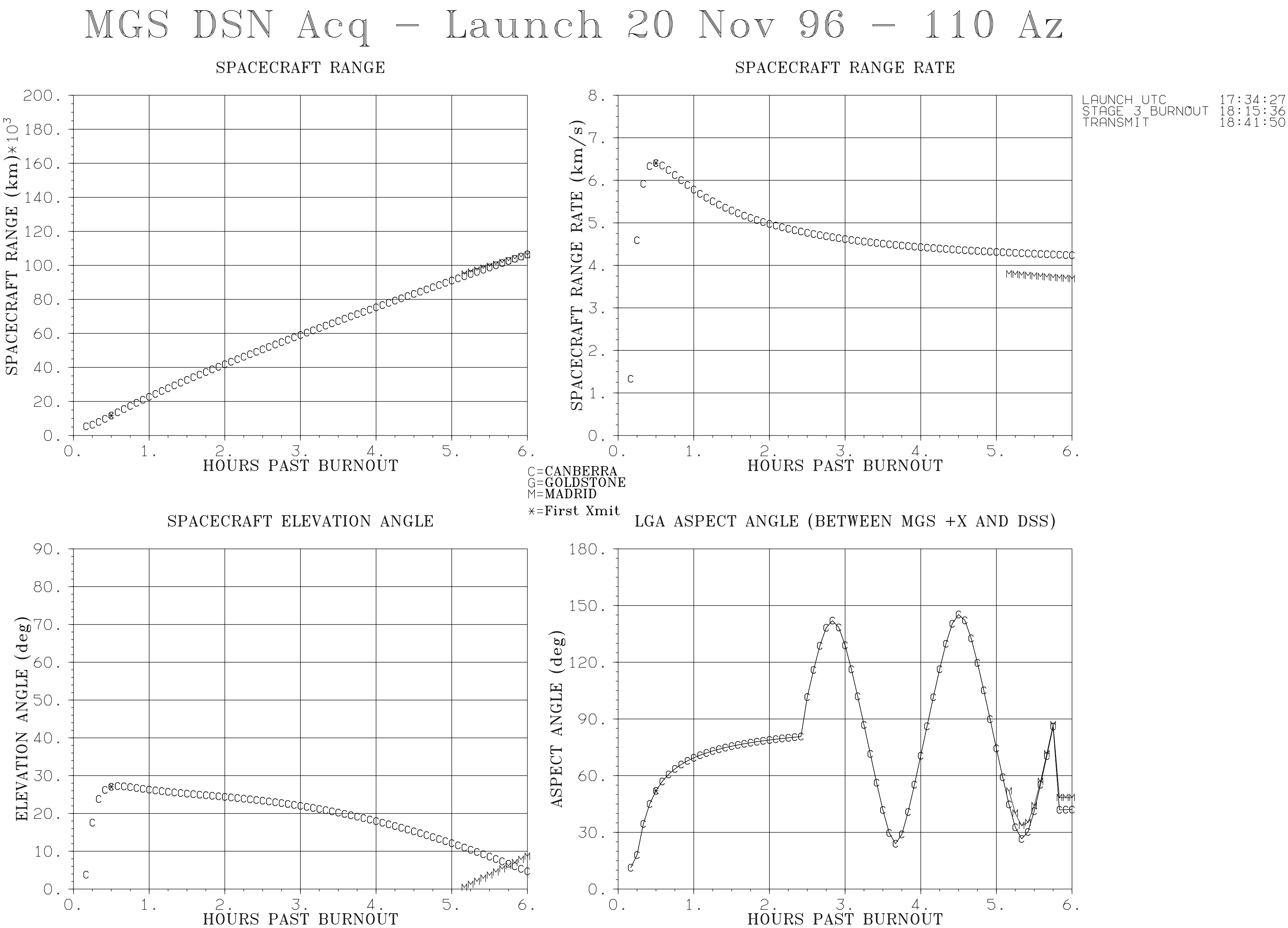


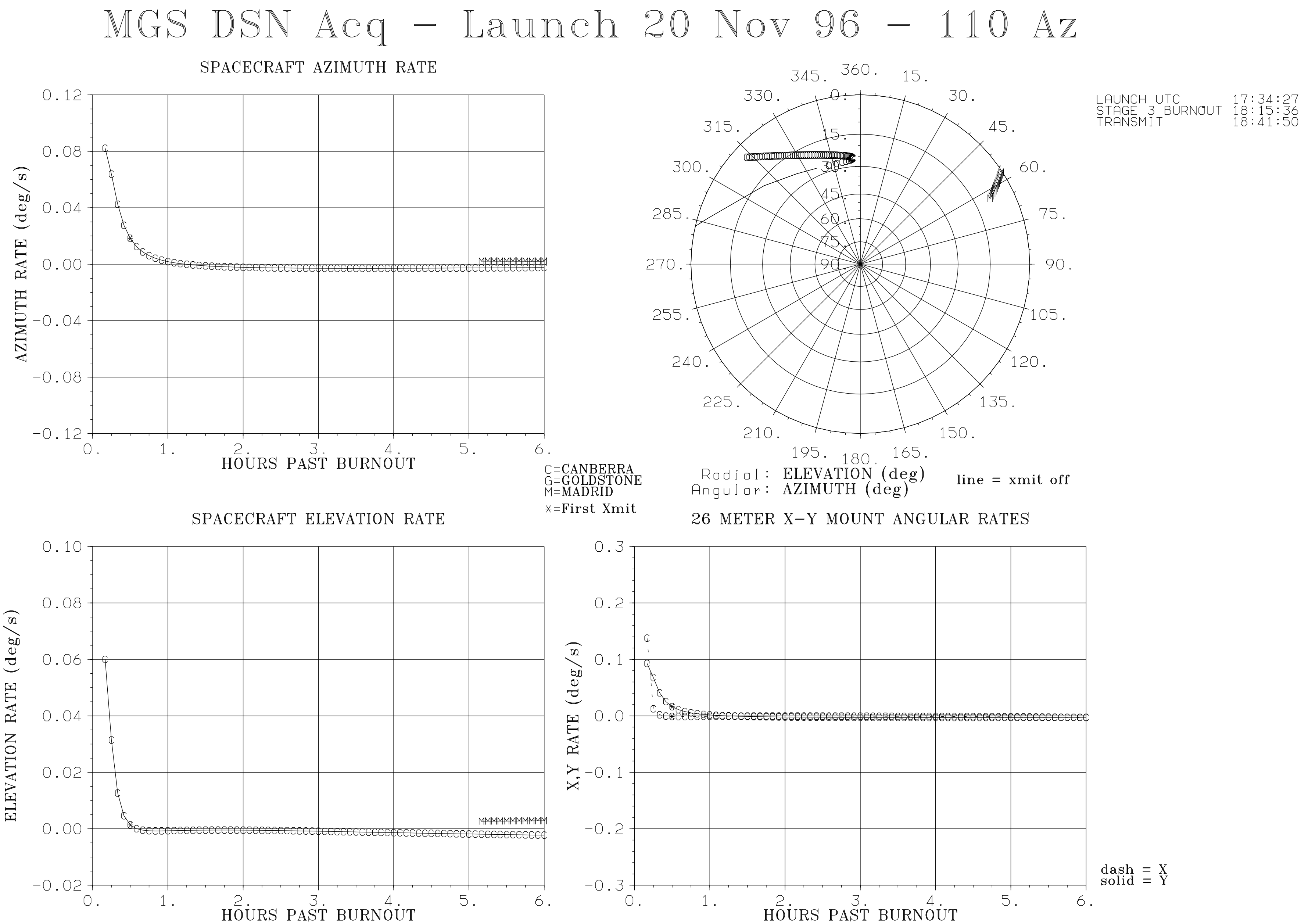


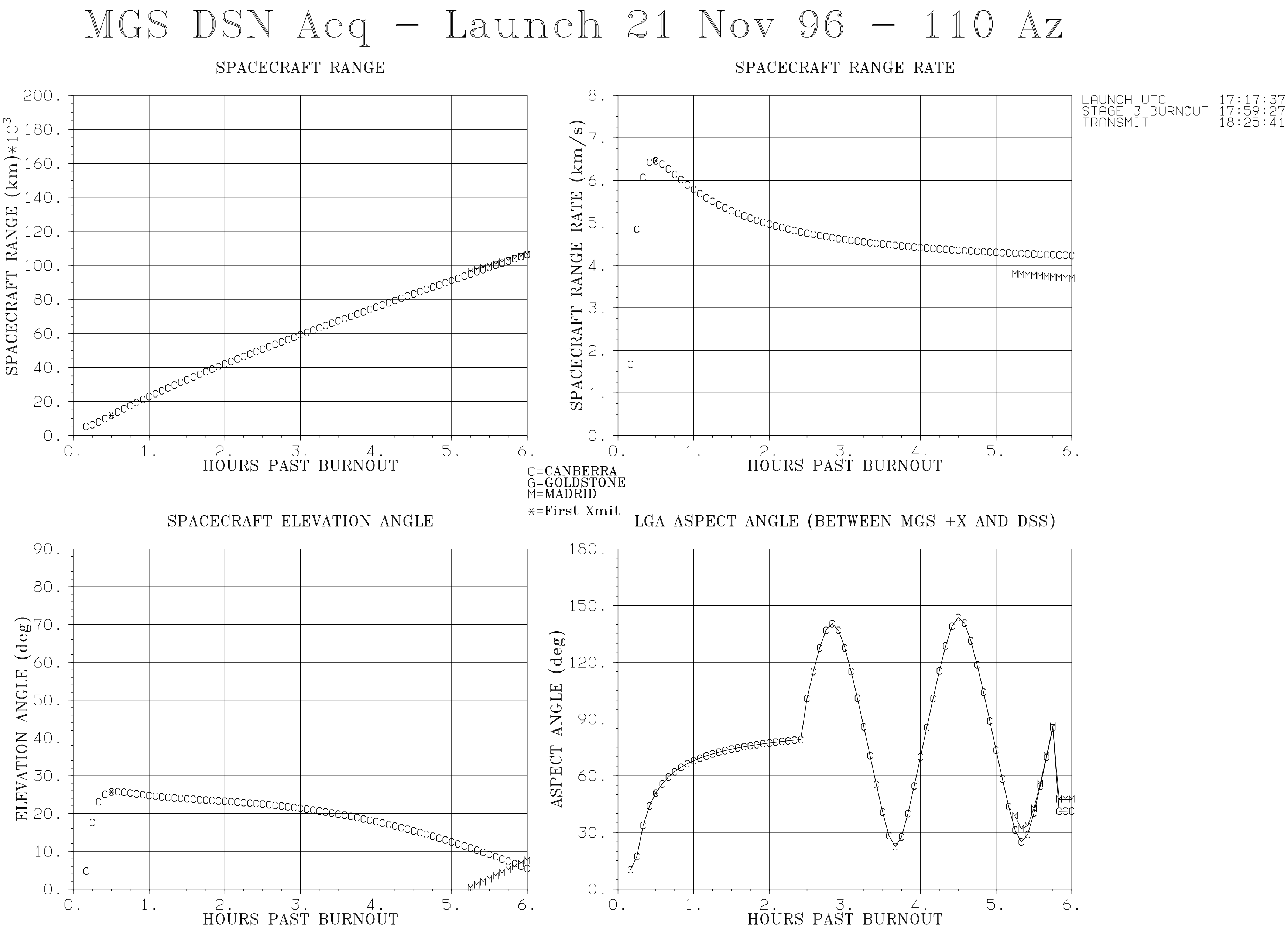

MGS DSN Acq - Launch 19 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 17:52:40
STAGE 3 BURNOUT 18:33:06
TRANSMIT 18:59:20
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

MGS DSN Acq – Launch 19 Nov 96 – 110 Az



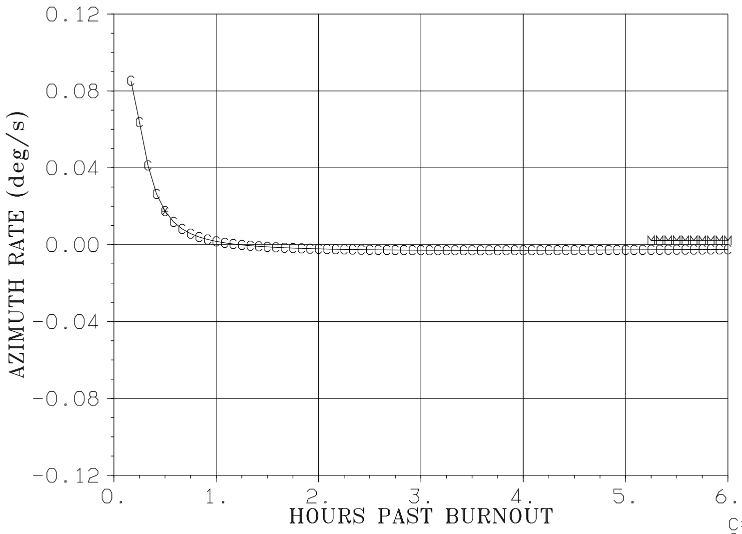

MGS DSN Acq - Launch 20 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 17:34:27
STAGE 3 BURNOUT 18:15:36
TRANSMIT 18:41:50
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

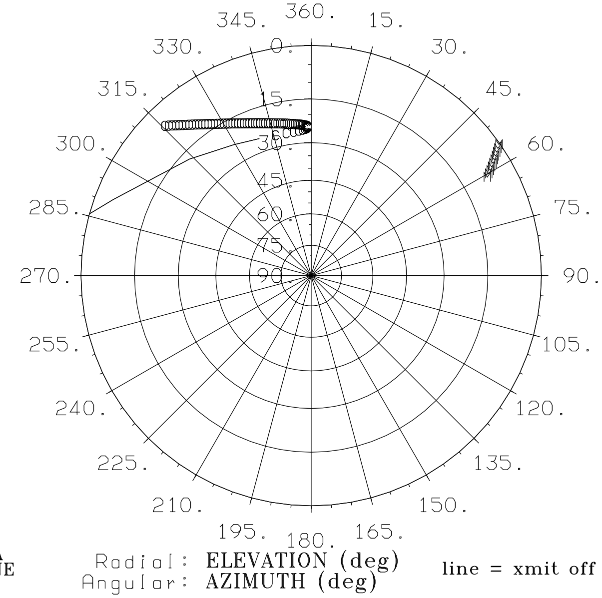

MGS DSN Acq - Launch 20 Nov 96 - 110 Az
SPACECRAFT AZIMUTH RATE
AZIMUTH RATE (deg/s)
HOURS PAST BURNOUT
LAUNCH UTC 17:34:27
STAGE 3 BURNOUT 18:15:36
TRANSMIT 18:41:50
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)
line = xmit off
SPACECRAFT ELEVATION RATE
ELEVATION RATE (deg/s)
HOURS PAST BURNOUT
26 METER X-Y MOUNT ANGULAR RATES
X,Y RATE (deg/s)
HOURS PAST BURNOUT
dash = X
solid = Y


MGS DSN Acq - Launch 21 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
LAUNCH UTC 17:17:37
STAGE 3 BURNOUT 17:59:27
TRANSMIT 18:25:41
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)

MGS DSN Acq – Launch 21 Nov 96 – 110 Az

SPACECRAFT AZIMUTH RATE

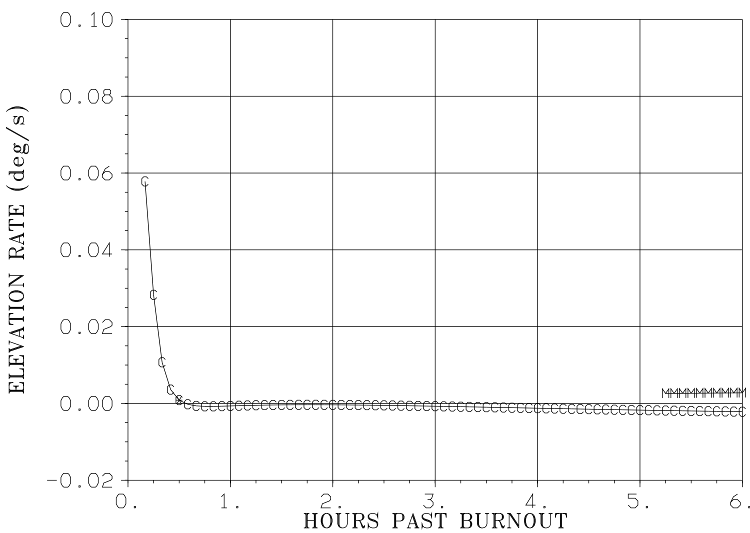




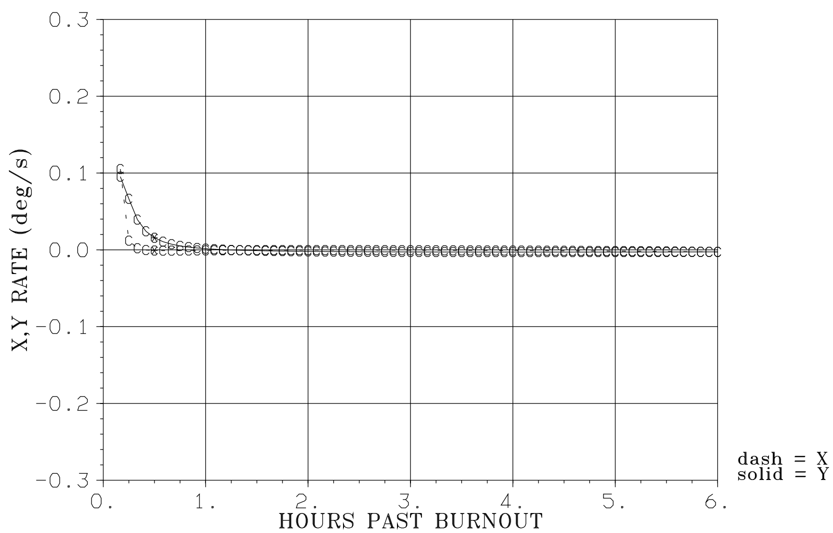
LAUNCH UTC 17:17:37
STAGE 3 BURNOUT 17:59:27
TRANSMIT 18:25:41

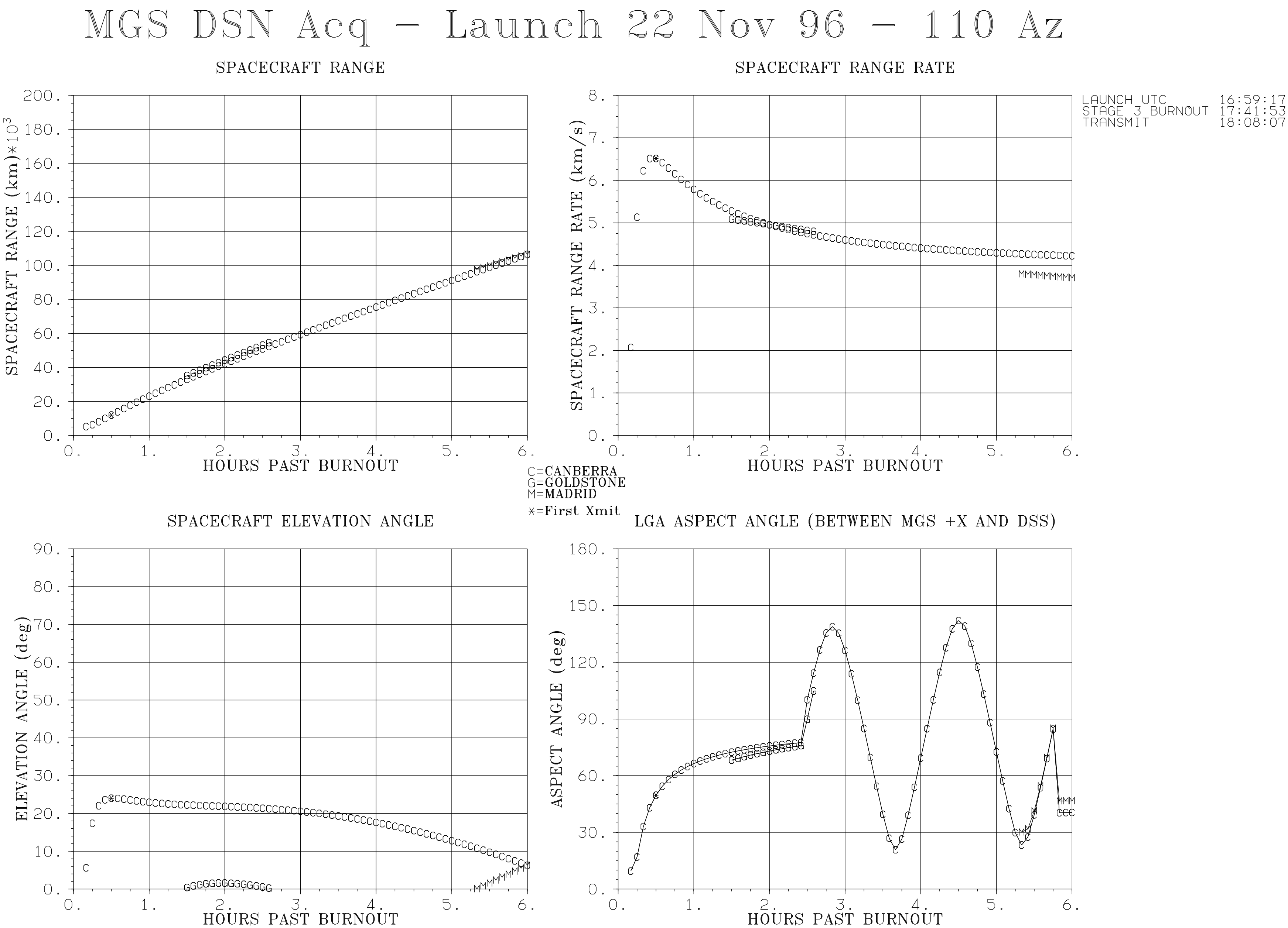
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

SPACECRAFT ELEVATION RATE

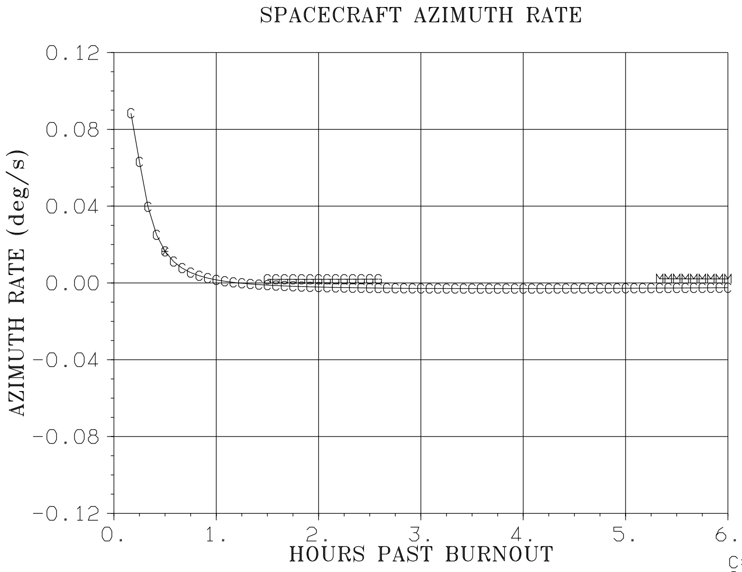


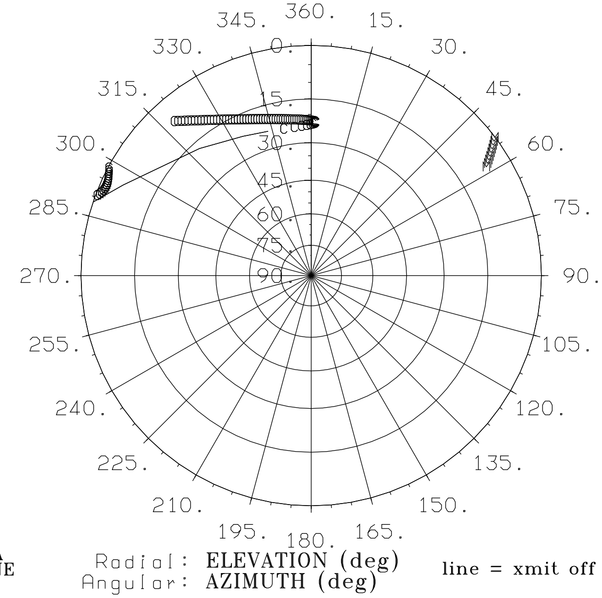
26 METER X-Y MOUNT ANGULAR RATES




MGS DSN Acq - Launch 22 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:59:17
STAGE 3 BURNOUT 17:41:53
TRANSMIT 18:08:07
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

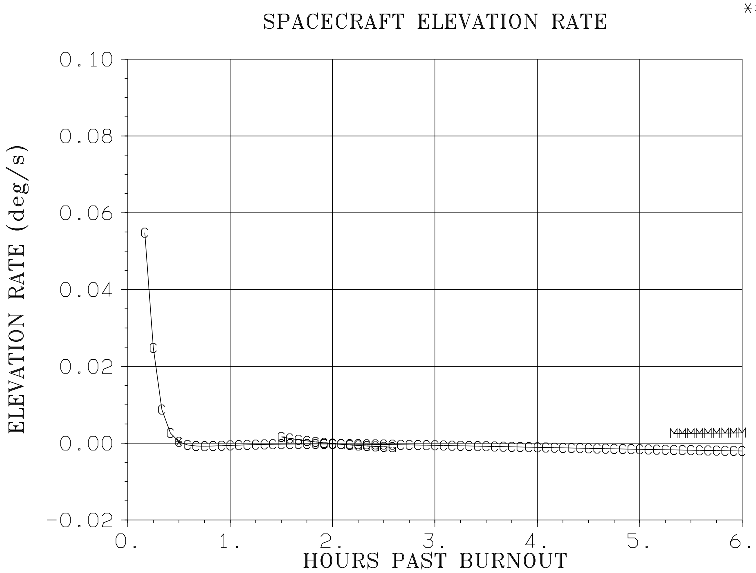
MGS DSN Acq – Launch 22 Nov 96 – 110 Az

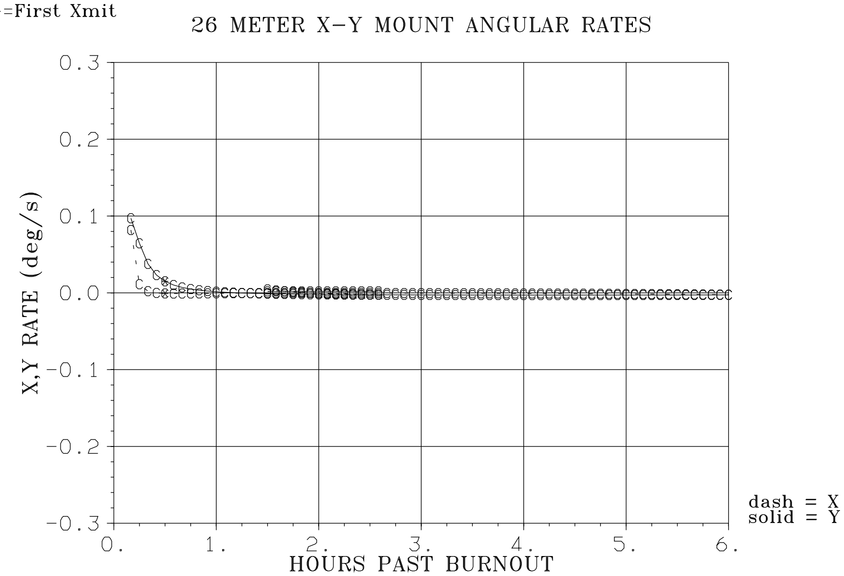


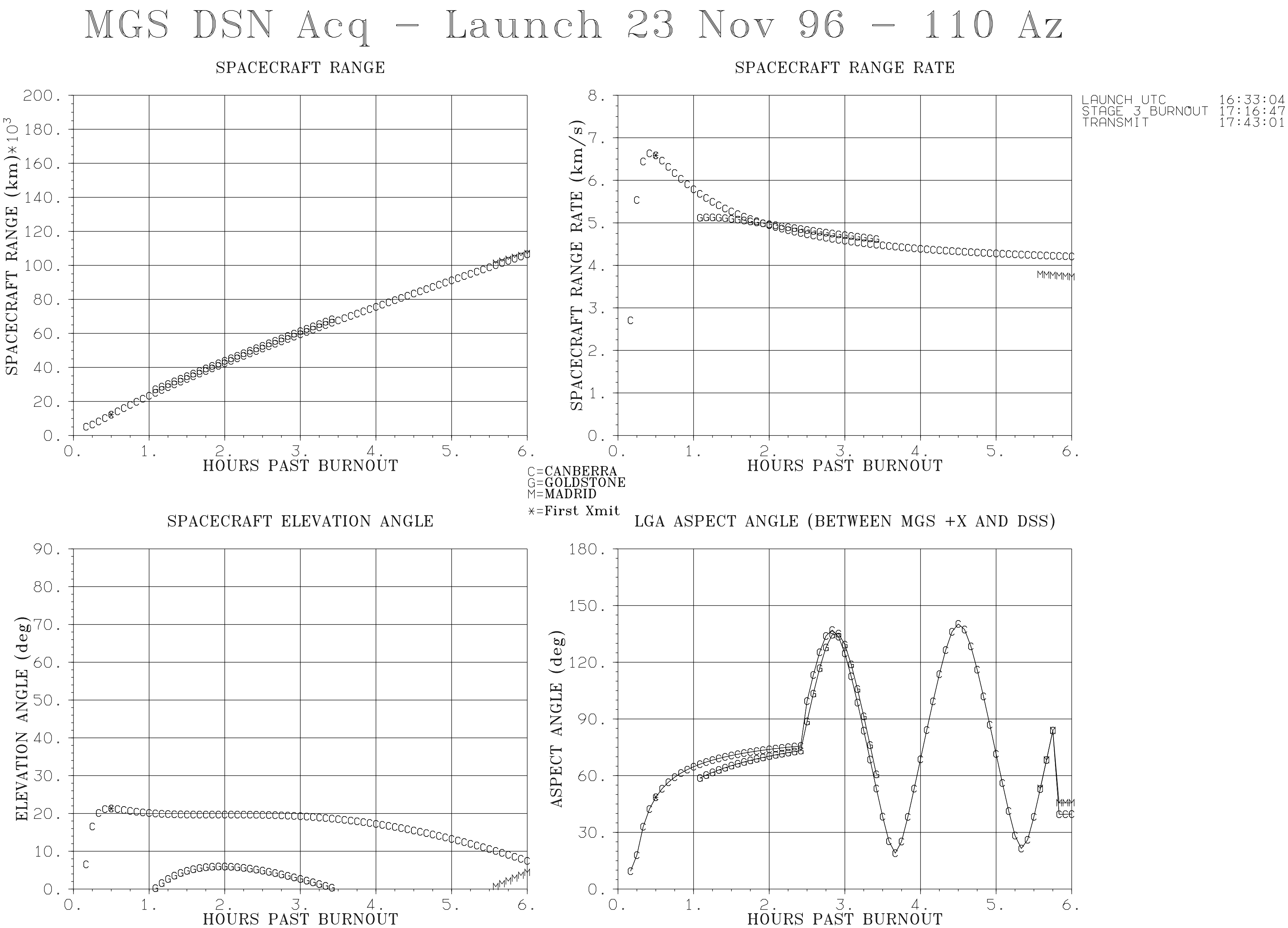


LAUNCH UTC 16:59:17
STAGE 3 BURNOUT 17:41:53
TRANSMIT 18:08:07

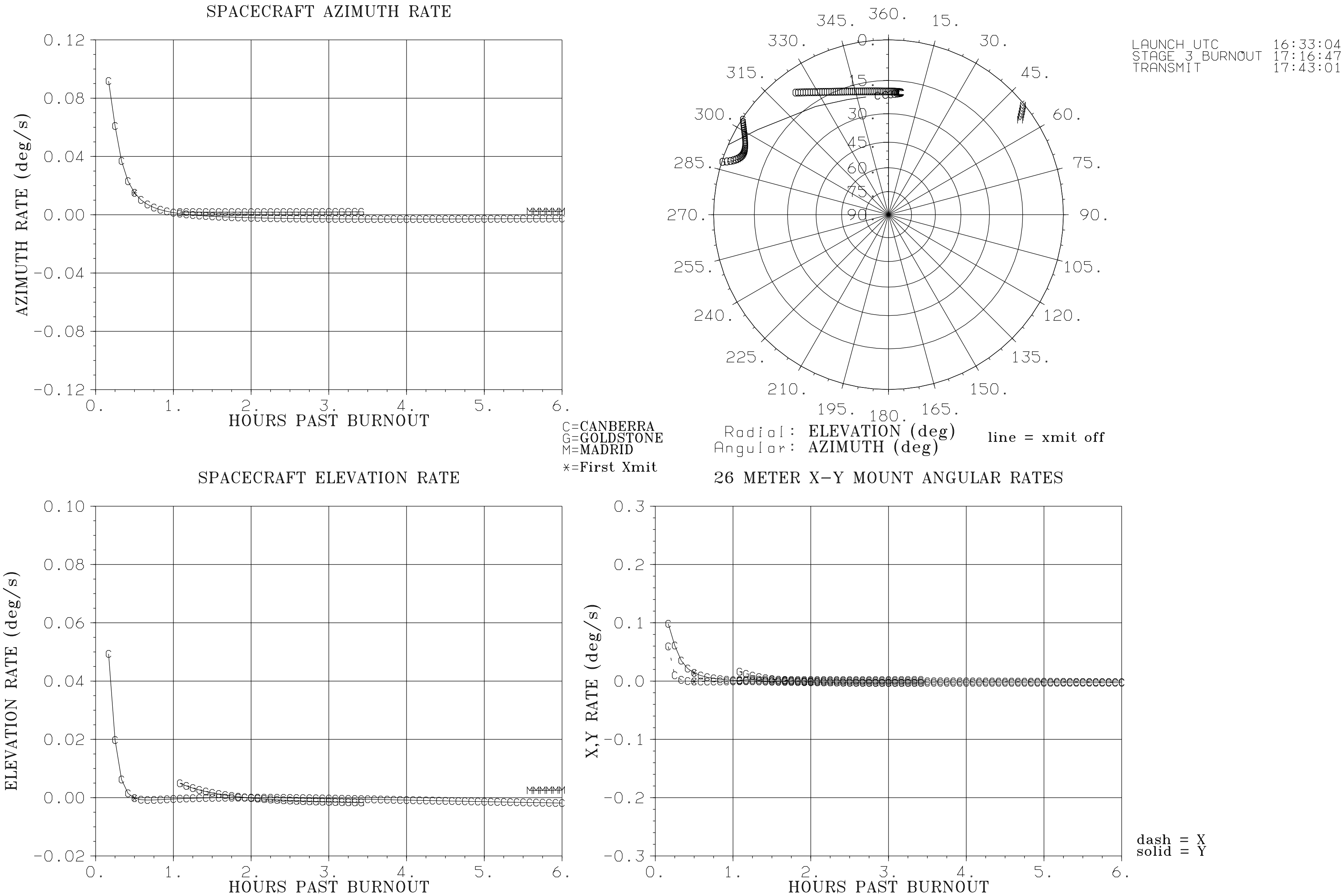
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit

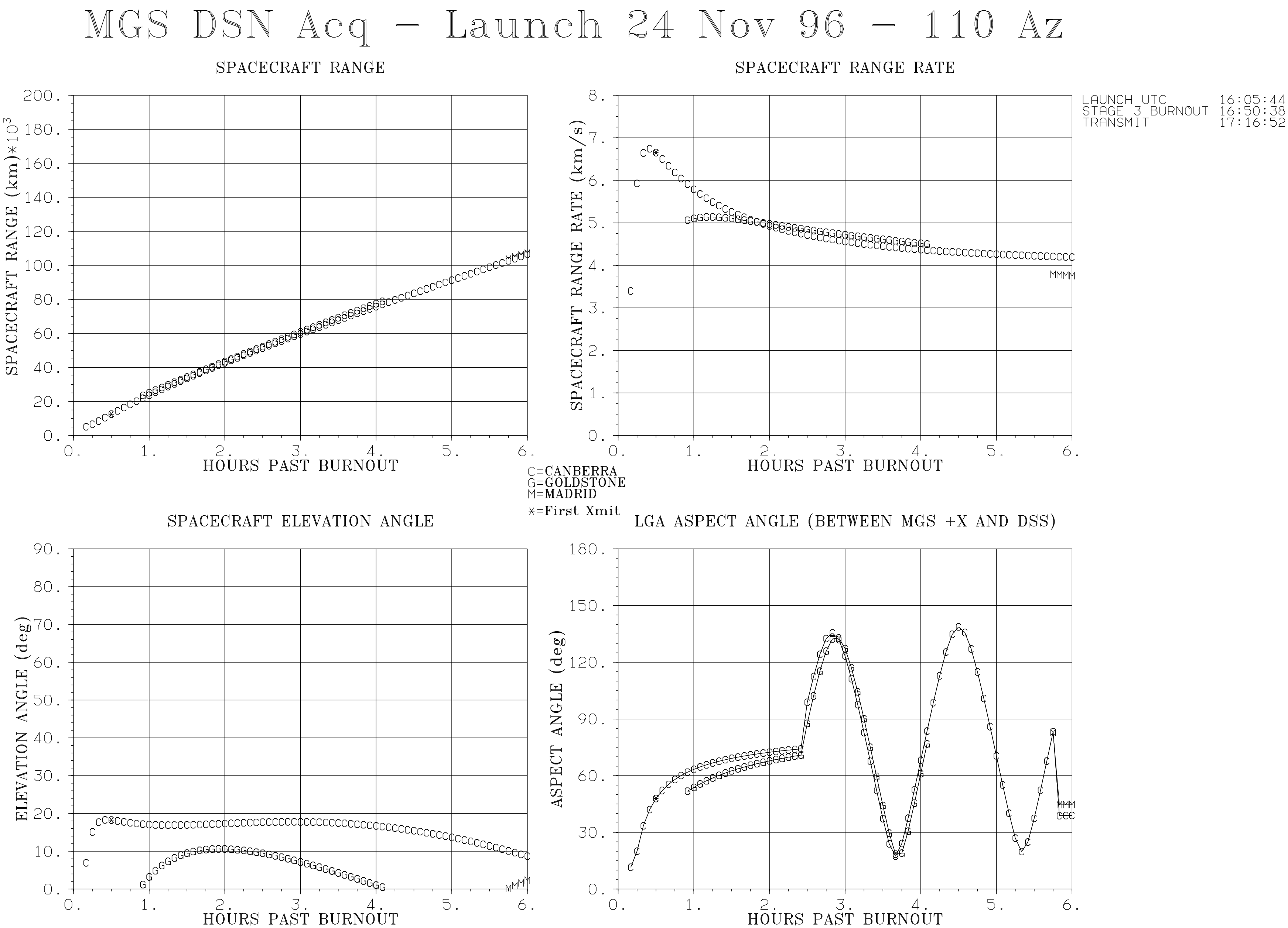


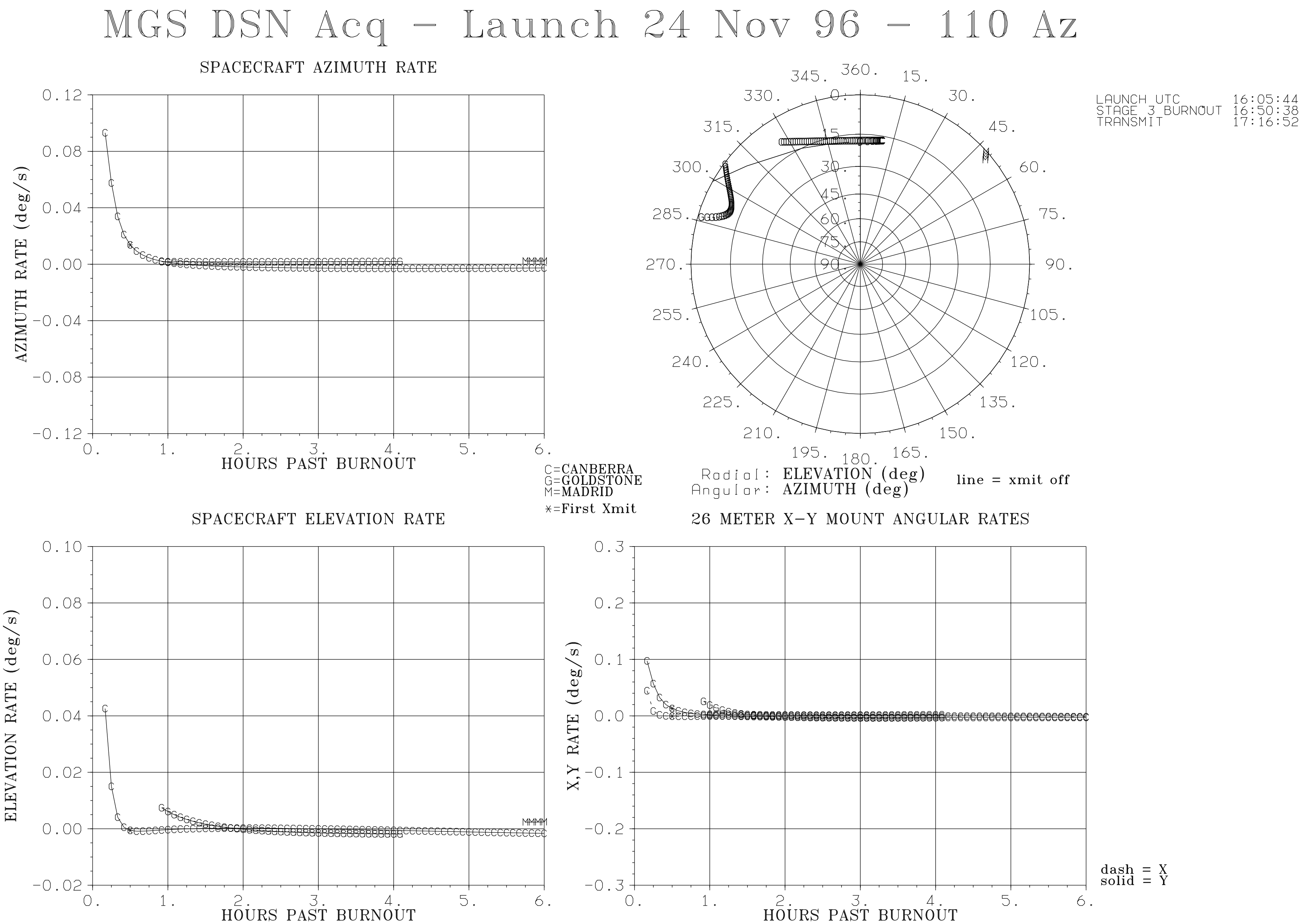


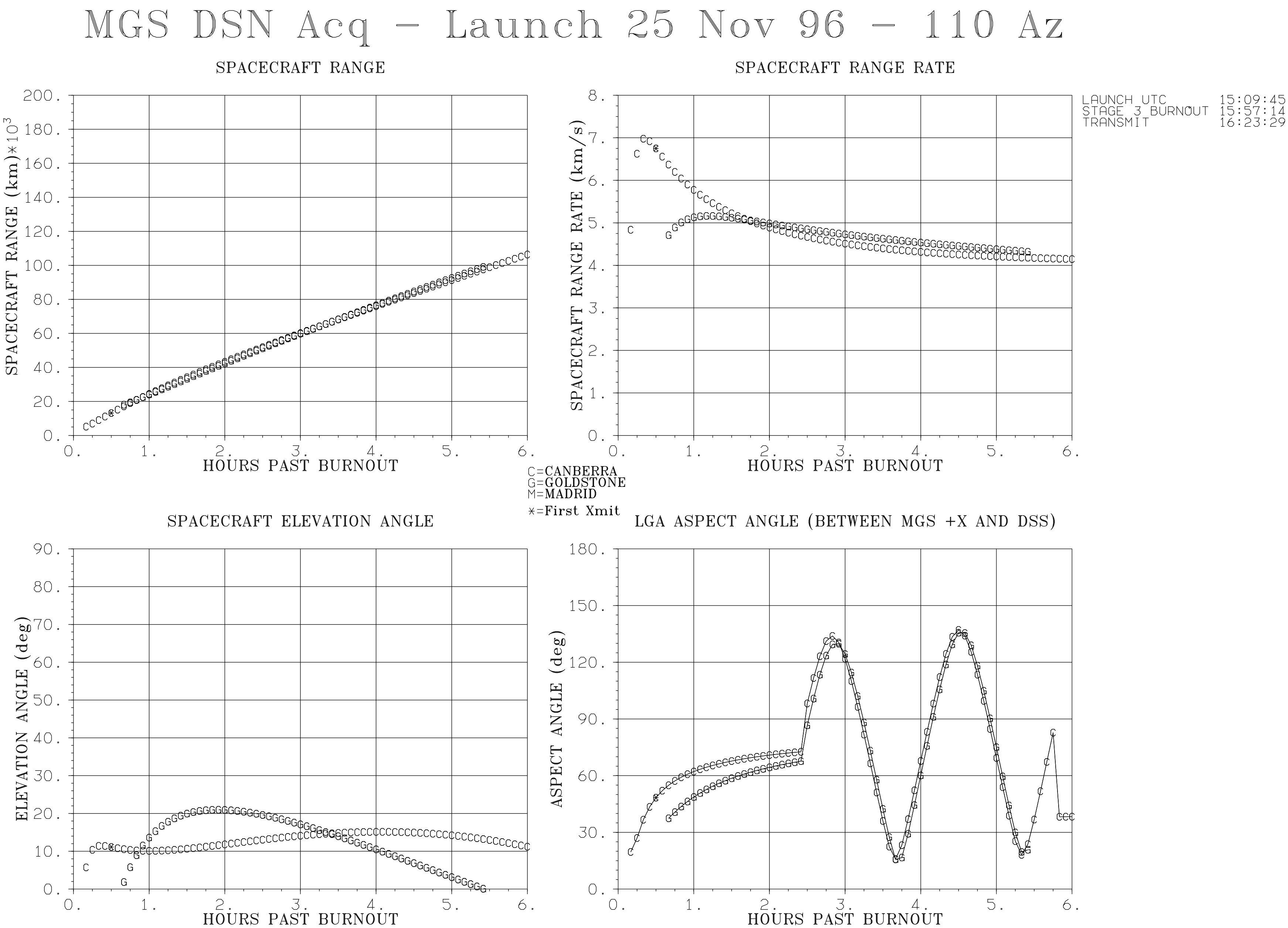

MGS DSN Acq - Launch 23 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:33:04
STAGE 3 BURNOUT 17:16:47
TRANSMIT 17:43:01
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

MGS DSN Acq - Launch 23 Nov 96 - 110 Az

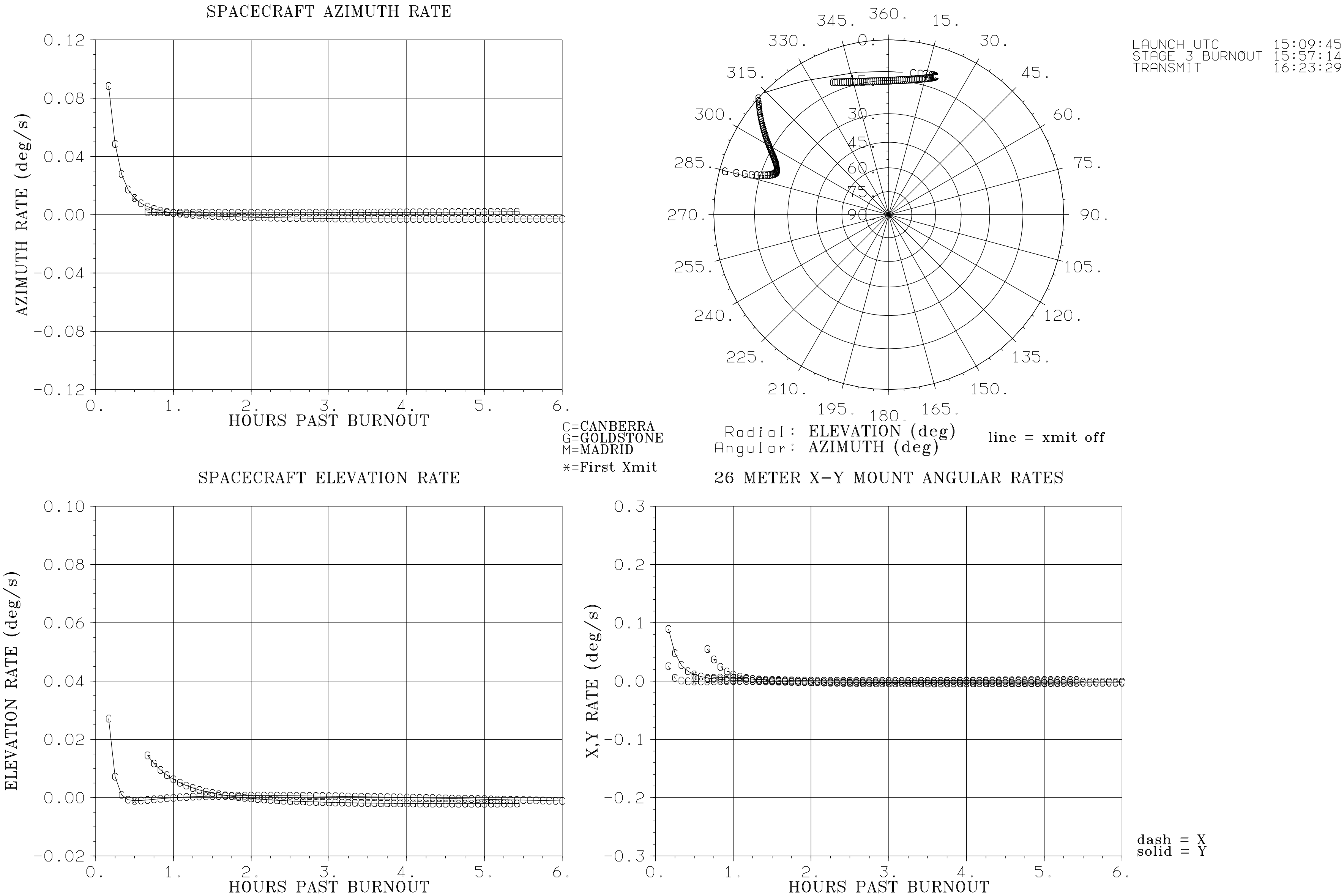



MGS DSN Acq - Launch 24 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
LAUNCH UTC 16:05:44
STAGE 3 BURNOUT 16:50:38
TRANSMIT 17:16:52
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)

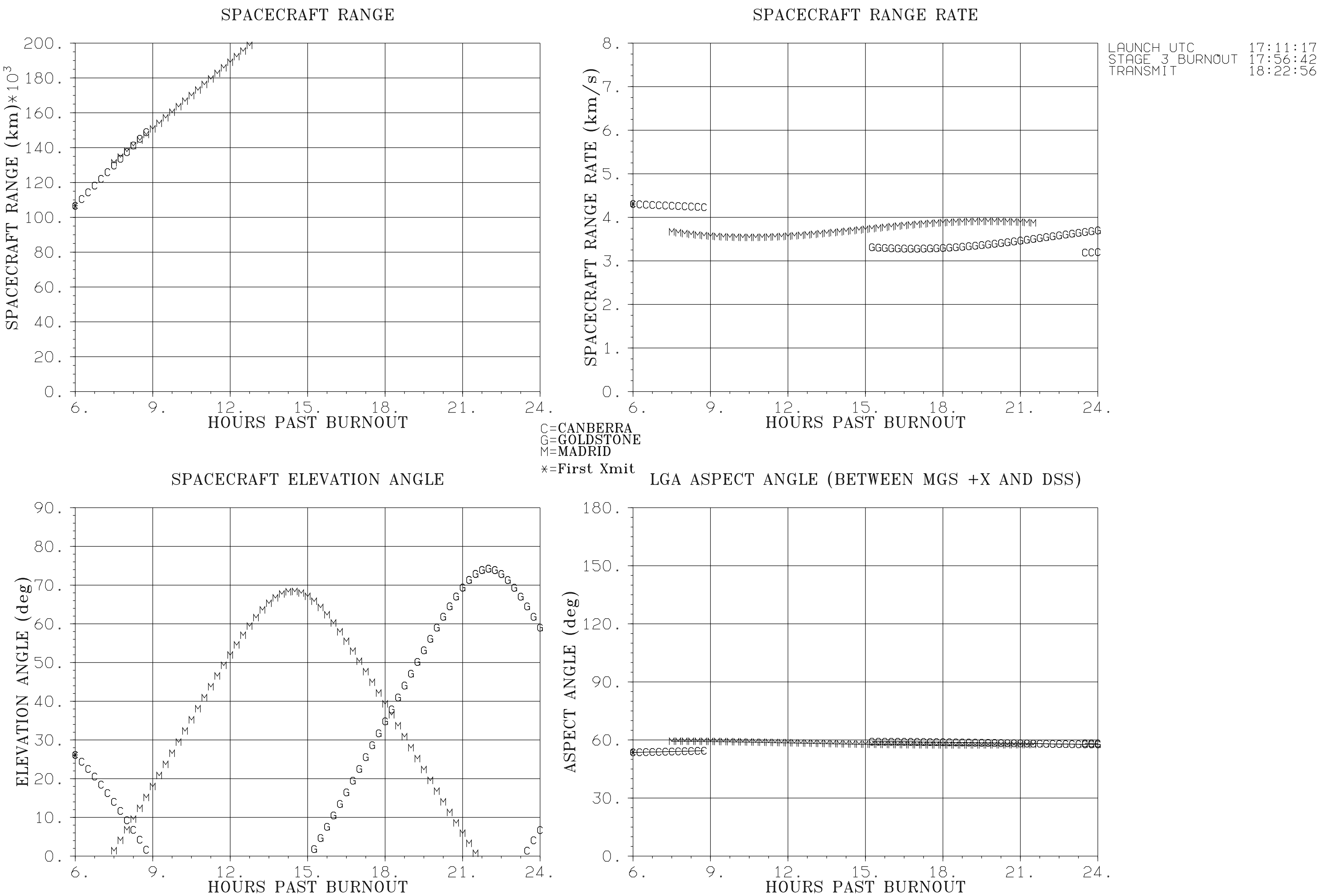

MGS DSN Acq - Launch 24 Nov 96 - 110 Az
SPACECRAFT AZIMUTH RATE
AZIMUTH RATE (deg/s)
HOURS PAST BURNOUT
LAUNCH UTC 16:05:44
STAGE 3 BURNOUT 16:50:38
TRANSMIT 17:16:52
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
Radial: ELEVATION (deg)
Angular: AZIMUTH (deg)
line = xmit off
SPACECRAFT ELEVATION RATE
ELEVATION RATE (deg/s)
HOURS PAST BURNOUT
26 METER X-Y MOUNT ANGULAR RATES
X,Y RATE (deg/s)
HOURS PAST BURNOUT
dash = X
solid = Y

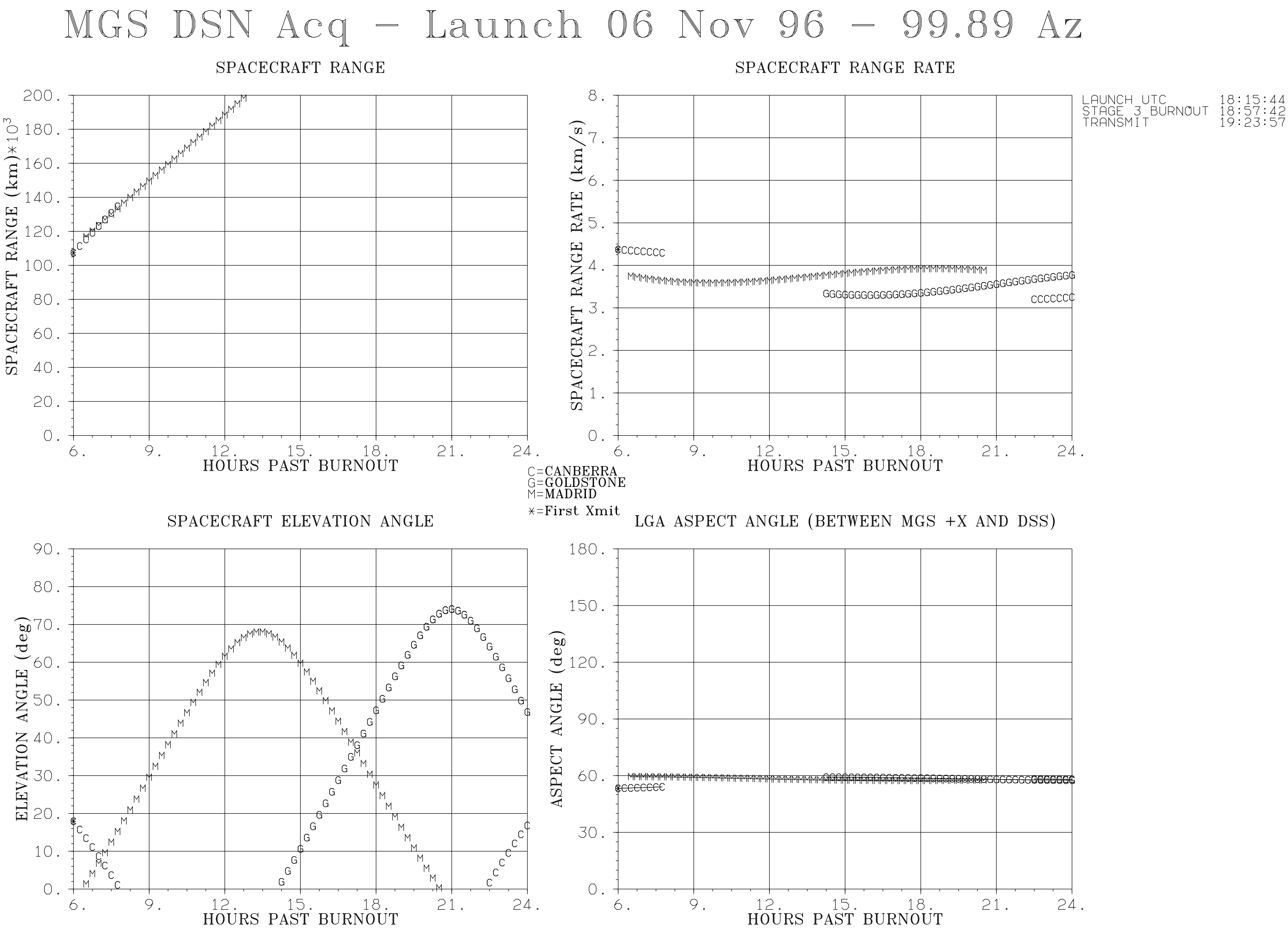

MGS DSN Acq - Launch 25 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 15:09:45
STAGE 3 BURNOUT 15:57:14
TRANSMIT 16:23:29
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

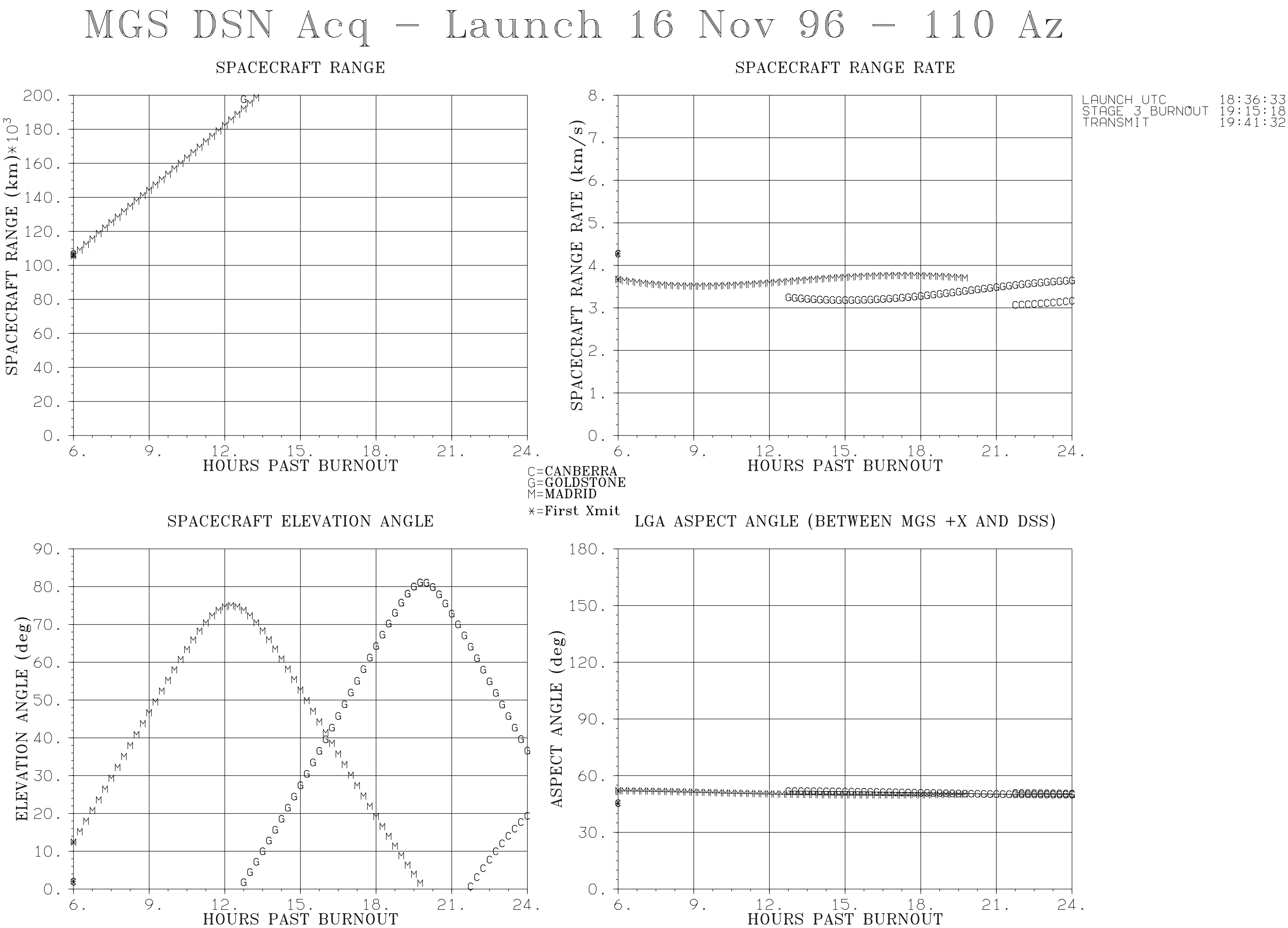
MGS DSN Acq – Launch 25 Nov 96 – 110 Az



MGS DSN Acq - Launch 06 Nov 96 - 93 Az

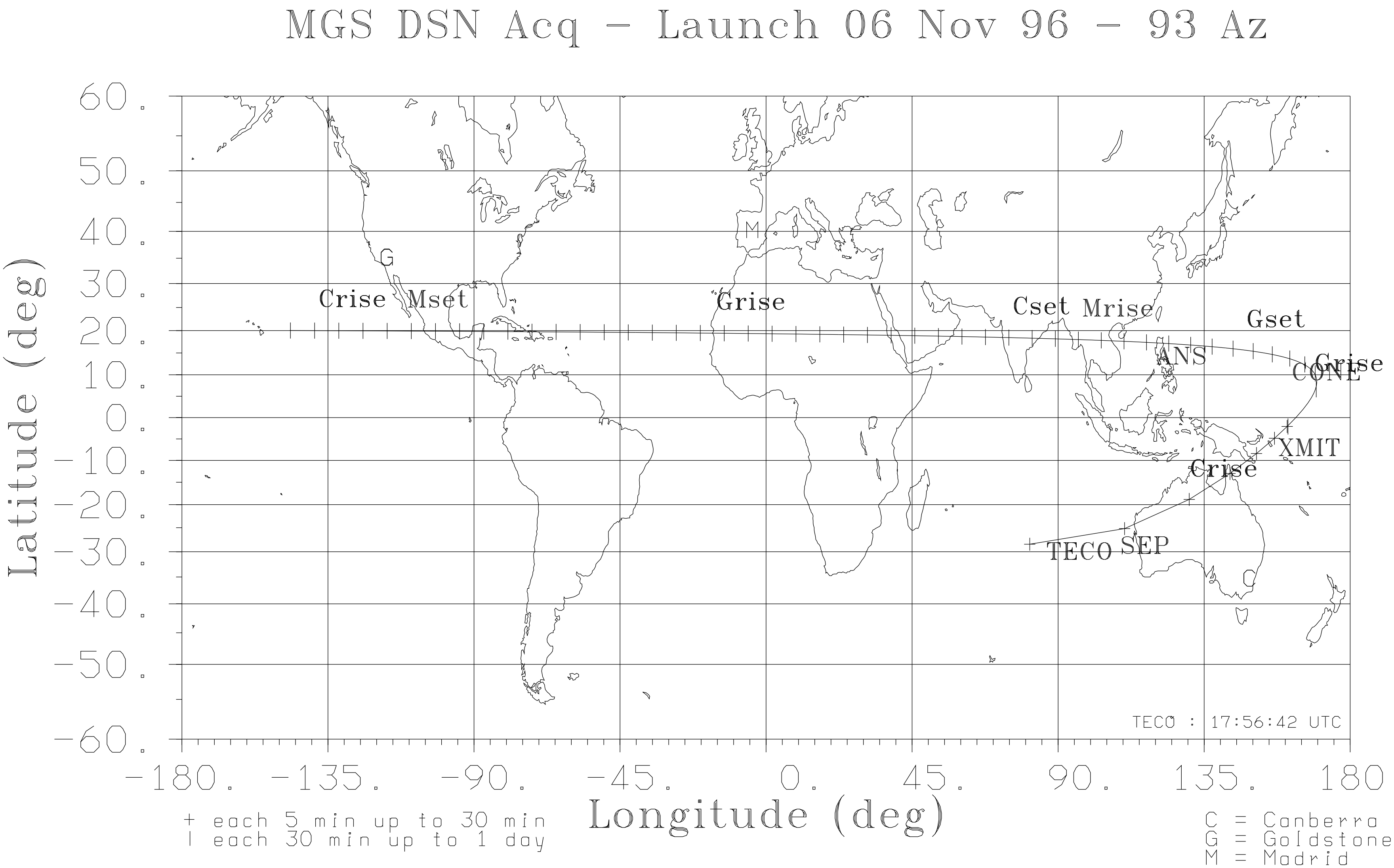


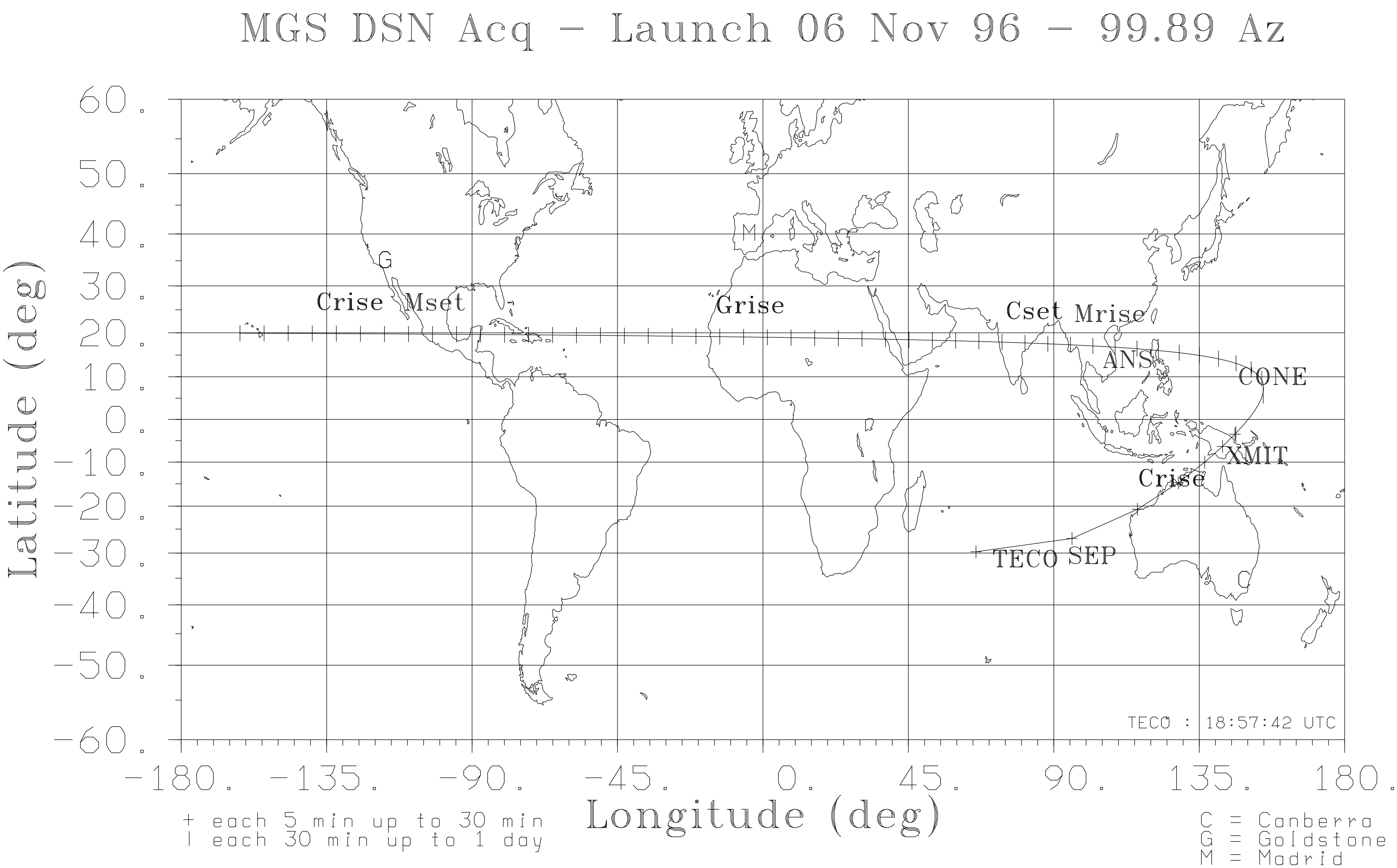

MGS DSN Acq - Launch 06 Nov 96 - 99.89 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 18:15:44
STAGE 3 BURNOUT 18:57:42
TRANSMIT 19:23:57
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

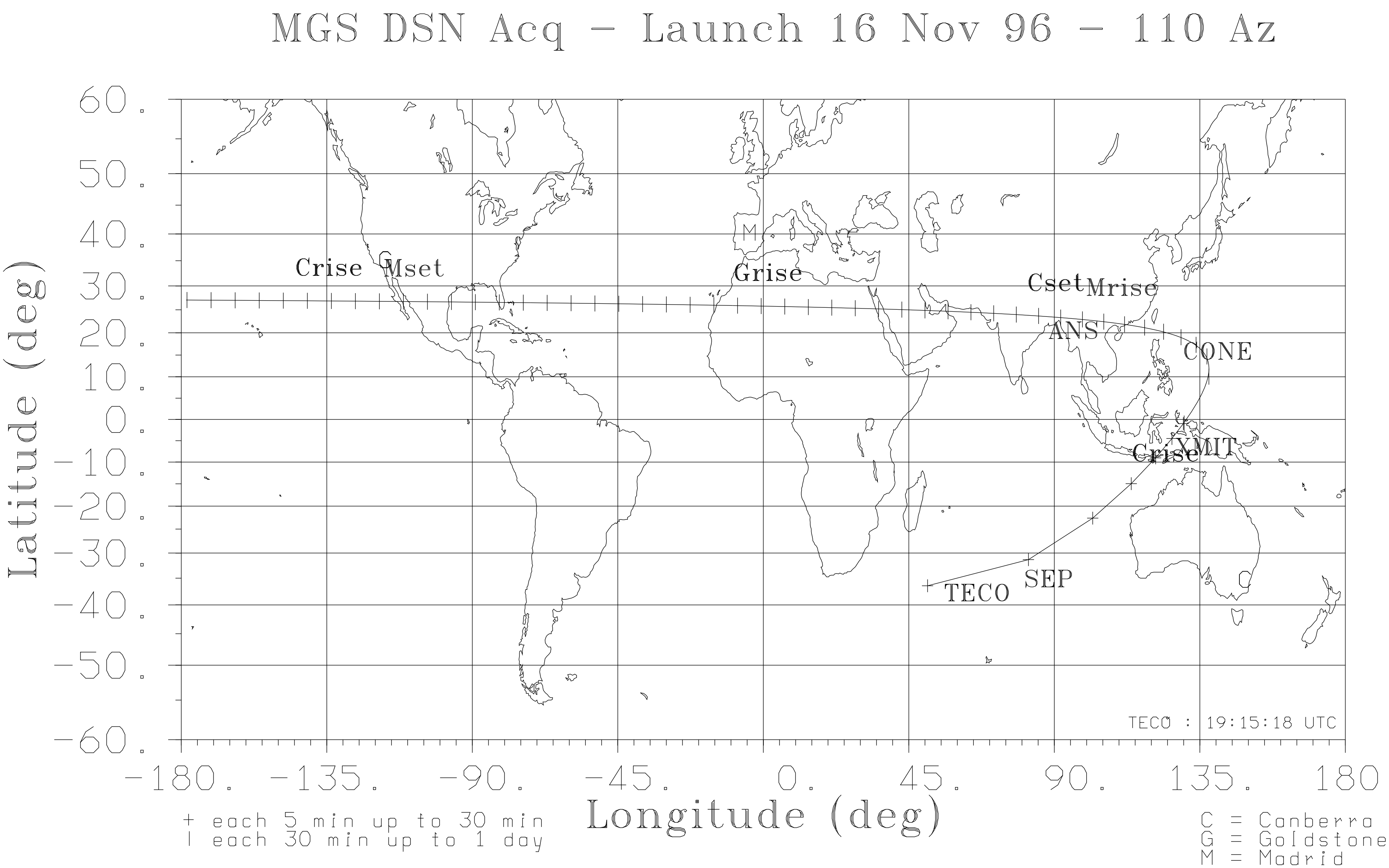

MGS DSN Acq - Launch 16 Nov 96 - 110 Az
SPACECRAFT RANGE
SPACECRAFT RANGE (km)*10^3
HOURS PAST BURNOUT
SPACECRAFT RANGE RATE
SPACECRAFT RANGE RATE (km/s)
HOURS PAST BURNOUT
LAUNCH UTC 18:36:33
STAGE 3 BURNOUT 19:15:18
TRANSMIT 19:41:32
C=CANBERRA
G=GOLDSTONE
M=MADRID
*=First Xmit
SPACECRAFT ELEVATION ANGLE
ELEVATION ANGLE (deg)
HOURS PAST BURNOUT
LGA ASPECT ANGLE (BETWEEN MGS +X AND DSS)
ASPECT ANGLE (deg)
HOURS PAST BURNOUT

3.6 GROUNDTRACK PLOTS

The last set of plots shows the groundtrack of the MGS spacecraft on a Mercator map projection with DSN station locations and annotations of TECO and rise/set events for 3 launch opportunities (November 6th, both azimuths, and November 16th). Due to the increasing declination target from one launch day to the next, the maximum latitude reached increases from 20° on November 6th to 28° on November 15th, and from 28° on November 16th to 36° on November 25th.


MGS DSN Acq - Launch 06 Nov 96 - 93 Az
Latitude (deg)
Longitude (deg)
60.
50.
40.
30.
20.
10.
0.
-10.
-20.
-30.
-40.
-50.
-60.
-180.
-135.
-90.
-45.
0.
45.
90.
135.
180.
G
M
C
Crise
Mset
Grise
Cset
Mrise
Gset
ANS
Grise
CONE
XMIT
Crise
SEP
TECO
TECO : 17:56:42 UTC
+ each 5 min up to 30 min
| each 30 min up to 1 day
C = Canberra
G = Goldstone
M = Madrid


MGS DSN Acq - Launch 06 Nov 96 - 99.89 Az
Latitude (deg)
Longitude (deg)
60.
50.
40.
30.
20.
10.
0.
-10.
-20.
-30.
-40.
-50.
-60.
-180.
-135.
-90.
-45.
0.
45.
90.
135.
180.
G
M
C
Crise
Mset
Grise
Cset
Mrise
ANS
CONE
XMIT
Crise
TECO
SEP
TECO : 18:57:42 UTC
+ each 5 min up to 30 min
| each 30 min up to 1 day
C = Canberra
G = Goldstone
M = Madrid


MGS DSN Acq - Launch 16 Nov 96 - 110 Az
Latitude (deg)
Longitude (deg)
60.
50.
40.
30.
20.
10.
0.
-10.
-20.
-30.
-40.
-50.
-60.
-180.
-135.
-90.
-45.
0.
45.
90.
135.
180.
Crise
G
Mset
M
Grise
Cset
Mrise
ANS
CONE
XMIT
Crise
SEP
TECO
C
TECO : 19:15:18 UTC
+ each 5 min up to 30 min
| each 30 min up to 1 day
C = Canberra
G = Goldstone
M = Madrid

4.0 REFERENCES

"Detailed Test Objectives Trajectories for the Mars Global Surveyor Spacecraft Mission - CDRL C3-04 - Contract NAS5-30722", McDonnell Douglas Memorandum A3-L230-M-96-XXX, Preliminary, May 1996

"Mars Global Surveyor Delta II 7925A Target Specification", JPL D-12728 (MGS 542-411), Final, February 1996

"Mars Global Surveyor Spacecraft Launch Event Timeline", JPL D-12888 (MGS 542-SE-014), Draft Revision B, February 1996

E. J. Graat, "Mars Global Surveyor Launch & Cruise Lockfile Version 1.0," JPL Interoffice Memorandum MGS-MOS-96-045, 29 April 1996

"Deep Space Network / Flight Project Interface Design Handbook", JPL 810-5, Rev. D, Vol. 1, 1 May 1992, p. 17

ACRONYMS AND TERMS

ACQ-AID	Acquisition Aid (antenna)
ANS	Array Normal Spin
bps	bits per second
COLA	Collision Avoidance
CONE	Sun-coning for attitude initialization
DSN	Deep Space Network
DSS	Deep Space Station
DTO	Development Test Objectives
ETR	Eastern Test Range
GMT	Greenwich Mean Time (assumed equivalent to UTC)
GVPAT	McDonnell Douglas trajectory software
HEF	High Efficiency (antenna)
LGA	Low Gain Antenna
LOX	Liquid Oxygen
MDA	McDonnell Douglas Aerospace
MECO	Main Engine Cutoff
MET	Mission Elapsed Time
MGS	Mars Global Surveyor
rpm	revolutions per minute
S/A	Solar Array
SECO	Second Engine Cutoff
SEP	Separation of MGS from Delta third stage
SLC	Space Launch Complex
TECO	Third Engine Cutoff
TIP	Targeting Interface Point
TWTA	Traveling Wave Tube Amplifier
UTC	Universal Time, Coordinated (assumed equivalent to GMT)
XMIT	Transmit

Σ	Launch azimuth